# Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project


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Submission date: 19 June 2014


## N2Africa

### Putting nitrogen fixation to work for smallholder farmers in Africa

N2Africa is a project funded by The Bill & Melinda Gates Foundation by a grant to Plant Production Systems, Wageningen University who lead the project together with CIAT-TSBF, IITA and many partners in the Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda and Zimbabwe.

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Andrew Farrow, 2014. Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project, www.N2Africa.org, 56 pp.

# Table of contents

**1 Introduction ..... 5**
1.1 Stratification ..... 5
1.2 General Target Areas ..... 5
**2 Biophysical relevance of technology ..... 8**
2.1 Length of the growing period ..... 8
2.2 Temperature ..... 13
2.3 Agro-Ecological zones ..... 15
2.4 Soils ..... 19
2.5 Cropping systems ..... 20
2.6 Stratification according to biophysical relevance of the legume technology ..... 22
**3 Land availability, quality or tenure ..... 23**
3.1 Population density ..... 24
3.2 Stratification according to land availability, quality or tenure ..... 26
**4 Output market for agricultural (legume) products ..... 28**
**5 Adoption domains ..... 34**
**6 References ..... 40**

# Table of tables

Table 1 Constraints to the adoption of BNF technologies and practices that can be managed using stratification in the research design ..... 5
Table 2. Regions and major grain legumes N2Africa will work with in Ethiopia ..... 6
Table 3. N2Africa partners within the regions and 'best bet' legume crops for target woredas within these areas ..... 6
Table 4. Length of Growing Period in Ethiopia per target woreda in each region ..... 9
Table 5. Potential stratification using growing period zones per crop per region ..... 13
Table 6. Growing Period zones per target woreda in each region ..... 13
Table 7. Traditional agro-ecological belts per target woreda in each region ..... 15
Table 8. LGP and temperature classes used in definition of agro-ecological zones in Ethiopia ..... 16
Table 9. Definition of agro-ecological zones in Ethiopia ..... 16
Table 10. Potential stratification using agro-ecological zones per crop per region ..... 19
Table 11. Agro-ecological zones per target woreda in each region ..... 19
Table 12. Livelihood zones per target woreda in each region ..... 21
Table 13. Common bean cropping systems per target woreda in each region ..... 22
Table 14. Stratification of target woredas according to the moisture regime in Ethiopia ..... 23

Table 15. Stratification of target woredas according to population density in Ethiopia ........................ 27
Table 16. Time threshold to reach different market types ................................................................... 28
Table 17. Markets per crop according to different market types in Ethiopia ........................................ 29
Table 18. Stratification of target woredas according to market access in Ethiopia .............................. 33
Table 19. Possible adoption domains based on binary stratification of key variables .......................... 34

# Table of figures

Figure 1. N2Africa Target Areas in Ethiopia ............................................................................................ 7
Figure 2. Length of Growing Period in Ethiopia. Source: van Velthuizen et al., 2007 ............................ 8
Figure 3. Length of Growing Period distribution per region in Ethiopia. Source: van Velthuizen et al., 2007 ........................................................................................................................................ 9
Figure 4. Seasonality per region in Ethiopia. Source: National Meteorological Agency, 2013 ............. 10
Figure 5. Growing Period Zones per region in Ethiopia. Source: National Meteorological Agency, 2013 ........................................................................................................................................ 11
Figure 6. Regions per Growing Period Zones in Ethiopia. Source: National Meteorological Agency, 2013 ........................................................................................................................................ 12
Figure 7. Regions per traditional agro-ecological Zones in Ethiopia. Source: Author's calculation based on SRTM elevation (Reuter et al., 2007) ............................................................................. 14
Figure 8. Agro-ecological zones in Ethiopia. Source: Source: Chamberlin et al., 2007........................ 17
Figure 9. Regions per agro-ecological Zones in Ethiopia. Source: Author's calculation based on Chamberlin et al., 2007 ........................................................................................................... 18
Figure 10. Humid and Dry moisture regimes in Ethiopia. Source: Chamberlin et al., 2007.................. 23
Figure 11. 2002 Rural population density in Ethiopia. Source: Chamberlin, 2007............................... 24
Figure 12. 2010 Population density in Ethiopia. Source: AfriPop 2010 (Linard et al., 2010) ................ 25
Figure 13. 2006 Population density in Ethiopia. Source: LandScan2006 (Bright et al., 2007) ............. 26
Figure 14. Population density threshold applied in Ethiopia ................................................................ 27
Figure 15. Access to common bean markets in Ethiopia ...................................................................... 30
Figure 16. Access to soybean markets in Ethiopia ............................................................................... 31
Figure 17. Access to chickpea markets in Ethiopia............................................................................... 32
Figure 18. Access to faba bean markets in Ethiopia ............................................................................. 33
Figure 19. Common bean adoption domains ........................................................................................ 35
Figure 20. Soybean adoption domains.................................................................................................. 36
Figure 21. Chickpea adoption domains................................................................................................. 37
Figure 22. Faba bean adoption domains............................................................................................... 38
Figure 23. Characterisation of target districts using adoption domains ............................................... 38

# 1 Introduction

## 1.1 Stratification

Options for the management of constraints to the adoption of grain legumes for biological nitrogen fixation include testing different mechanisms relating to the delivery and generation of knowledge and training, different models of seed multiplication and diffusion, the production, marketing and delivery of rhizobia and other inputs, and the community level the different models of selling and adding value to legume products. For other constraints that cannot be controlled but which will have an effect on the 'fit' of different legume technologies and practices, and the subsequent diversity of options it will be necessary to characterise the country and stratify those constraints so testing can take place at sites that are broadly representative of larger areas. These constraints include the climate and some general soil parameters, and to a certain extent land tenure and average land sizes, as well as some household/farm attributes.

The review of constraints to adoption and conditioning factors has shown that stratification can be applied at multiple levels (Farrow, 2014). The first level is the choice of the country which defines many institutional and policy conditions that affect the delivery and availability of agricultural inputs, knowledge and market opportunities. The next level of stratification is within the country to choose broad target areas. The variables that are used in this stratification step should exhibit more variability across the country than within the target area (a region). Further levels of stratification within districts and communities will be necessary (

Table 1) but this report concentrates on the stratification at the country level and characterisation of target areas, and districts within those target areas.

**Table 1 Constraints to the adoption of BNF technologies and practices that can be managed using stratification in the research design**

| Constraint | Scale / level of constraint |
|---|---|
| Biophysical relevance of technology | Multiple |
| Household access to Capital / Assets | Household |
| Land availability, quality or tenure | Multiple |
| Output market for agricultural (legume) products | Multiple |
| Availability of labour | Household and Community |
| Gender | Household and Community level |
| Education / literacy of the farm household members | Household and Community |
| Experience of the farm household members | Household |

## 1.2 General Target Areas

Some general target areas have been discussed in meetings among N2Africa partners and potential partners. These meetings have been guided by the current areas of operation of partners, their experience of particular legume crops as well as the production areas of grain legumes (Ronner et al., 2012).

In Ethiopia four regions have been chosen in which five grain legume crops are already a component of the farming system (Table 2). Each of these regions also has a main partner and different regional governance structures.

**Table 2. Regions and major grain legumes N2Africa will work with in Ethiopia**

| Region | Common bean | Soybean | Chickpea | Faba bean |
|---|---|---|---|---|
| Amhara – centred on Bahir Dar | | | | |
| Benishangul-Gumuz – centred on Pawe | | | | |
| Oromia – centred on Debre Zeit | | | | |
| Southern Nations, Nationalities and Peoples Republic (SNNPR) – centred on Hawassa | | | | |

Discussions with partners in Ethiopia have already identified a number of districts (woredas) where N2Africa could potentially work, as well as the legume crops which are considered suitable for those sites (Table 3). These legume crops are subsequently referred to as the 'best bet' legumes for the particular target areas based on expert knowledge.

**Table 3. N2Africa partners within the regions and 'best bet' legume crops for target woredas within these areas**

| Region | Partner | Target woredas | 'Best bet' legume crop |
|---|---|---|---|
| Amhara | Amhara Regional Agricultural Research Institute (ARARI) / Bahir Dar University | Farta | Faba Bean |
| | | Bichena | Chickpea |
| Benishangul-Gumuz | Ethiopian Institute of Agricultural Research (EIAR) - Pawe Agricultural Research center | Pawe | Soybean |
| | | Guanga (Guangua) | Common bean |
| Oromia | Oromia Regional Agricultural Research Institute (OARI) | Bakko (Bako Tibe) | Soybean<br>Common bean |
| | | Sinana | Faba bean |
| | EIAR - Debrezeit Agricultural Research Center | Akaki | Chickpea |
| | EIAR - Melkasa Agricultural Research center | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean |
| SNNPR | Hawassa University / Southern Agricultural Research Institute | Borcha (Boricha) | Common bean |
| | | Bodity (Damot Gale) | Chickpea |

The characterisation and suggestions for stratification in this report are focussed on these woredas which can be seen in Figure 1. The characterisation focusses on three factors affecting adoption that show variation across the country: (1) Biophysical relevance of technology; (2) Land availability, quality or tenure; and, (3) Output market for agricultural (legume) products. Within each of these categories the most appropriate indicators and data are sought and are summarised for the target woredas.

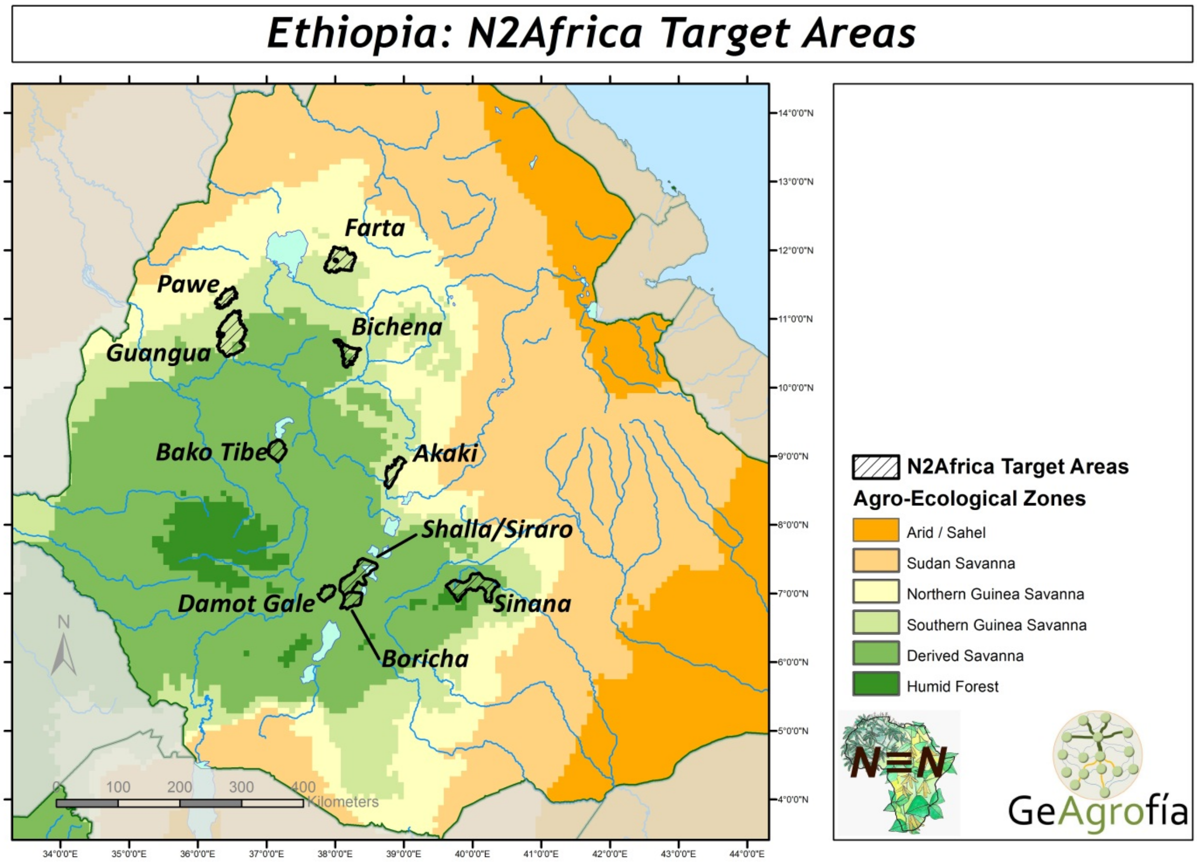


**Figure 1. N2Africa Target Areas in Ethiopia**

# 2 Biophysical relevance of technology

## 2.1 Length of the growing period

The principal factor determining the biophysical relevance of the technology is the ability to grow the particular legume crop during the growing season. The length of the growing season is calculated based on temperature and the soil moisture calculated as a ratio of actual and potential evaporation which depend on the soil water holding capacity and the precipitation .

In the regions of Ethiopia the length of the growing period (LGP) varies from practically zero in southern SNNPR to year-round growth in Oromia, on the border with eastern SNNPR (Figure 2).

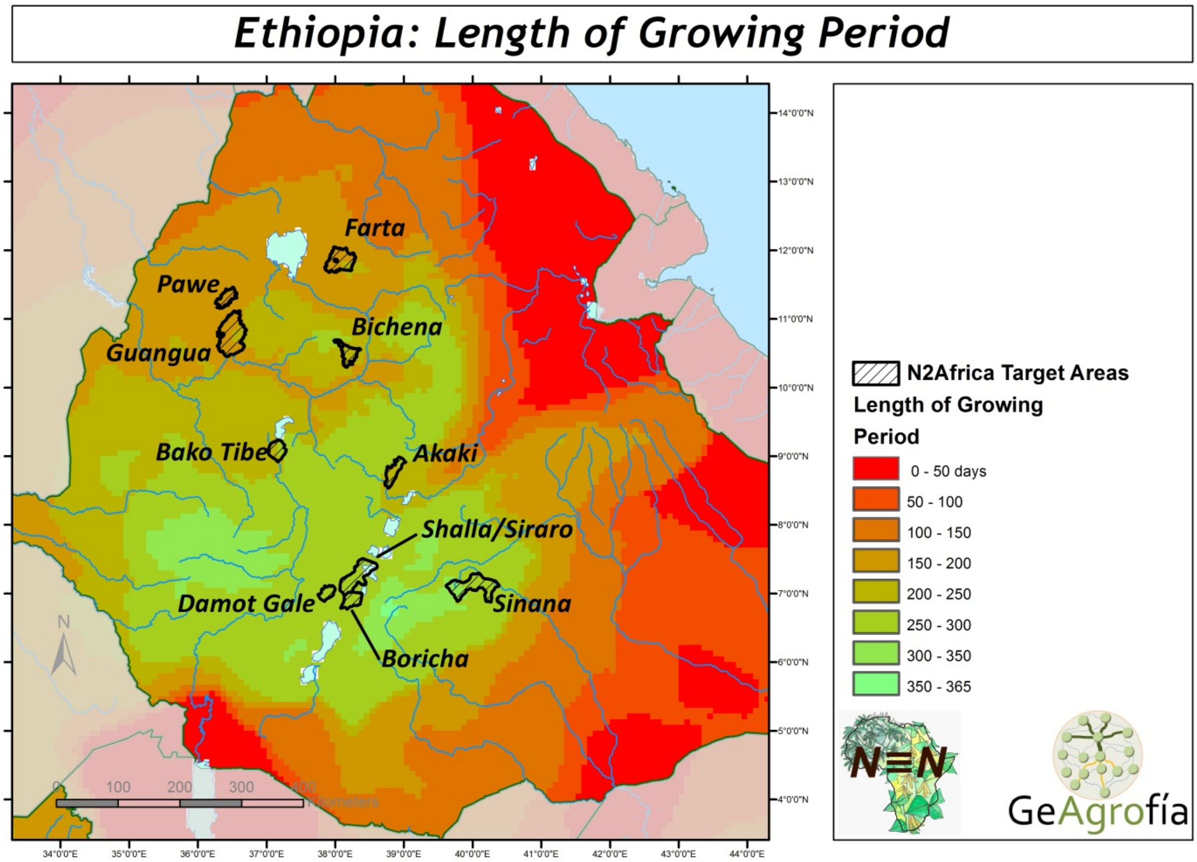


**Figure 2. Length of Growing Period in Ethiopia. Source: van Velthuizen et al., 2007**

For the purposes of stratification Oromia and Amhara offer the greatest diversity of zones with differing LGP (Figure 3). SNNPR also has a high diversity of zones but the absolute area is smaller. The target area with the most limited set of zones is Benishangul-Gumuz, although the same zones are found in the other three target areas.

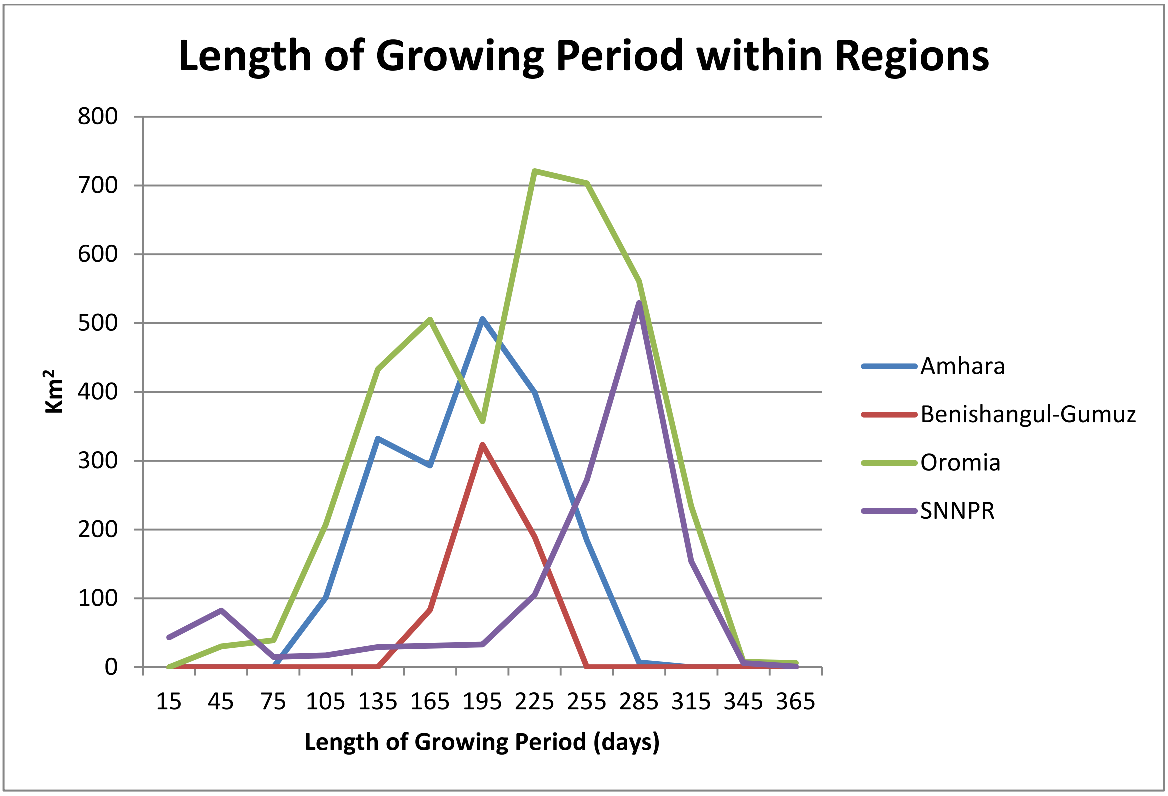


**Figure 3. Length of Growing Period distribution per region in Ethiopia. Source: van Velthuizen et al., 2007**

The length of the growing period is not shorter than 195 days in any of the target woredas, with a minimum in Amhara and Benishangul-Gumuz, and a maximum of 315 days in parts of Sinana woreda in Oromia (Table 4). Due to the small size of the woredas no single woreda has a great diversity of LGP zones.

**Table 4. Length of Growing Period in Ethiopia per target woreda in each region**

| Region | Target woredas | 'Best bet' legume crop | LGP days |
|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | 195 - 225 |
| | Bichena | Chickpea | 225 - 255 |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | 195 |
| | Guanga (Guangua) | Soybean, Common bean | 195-225 |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | 225-255 |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | 285 |
| | Bakko (Bako Tibe) | Soybean Common bean | 225-255 |
| | Sinana | Faba bean | 315 - 285 |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | 285 |
| | Bodity (Damot Gale) | Chickpea | 285 |

LGP provides a good indication of the overall agricltural potential, but within the target areas the characteristics of the growing seasons are different with Amhara, Benishangul-Gumuz, and the western part of Oromia characterised by unimodal rainfall, while southern SNNPR and eastern Oromia experience two growing seasons (Figure 4).

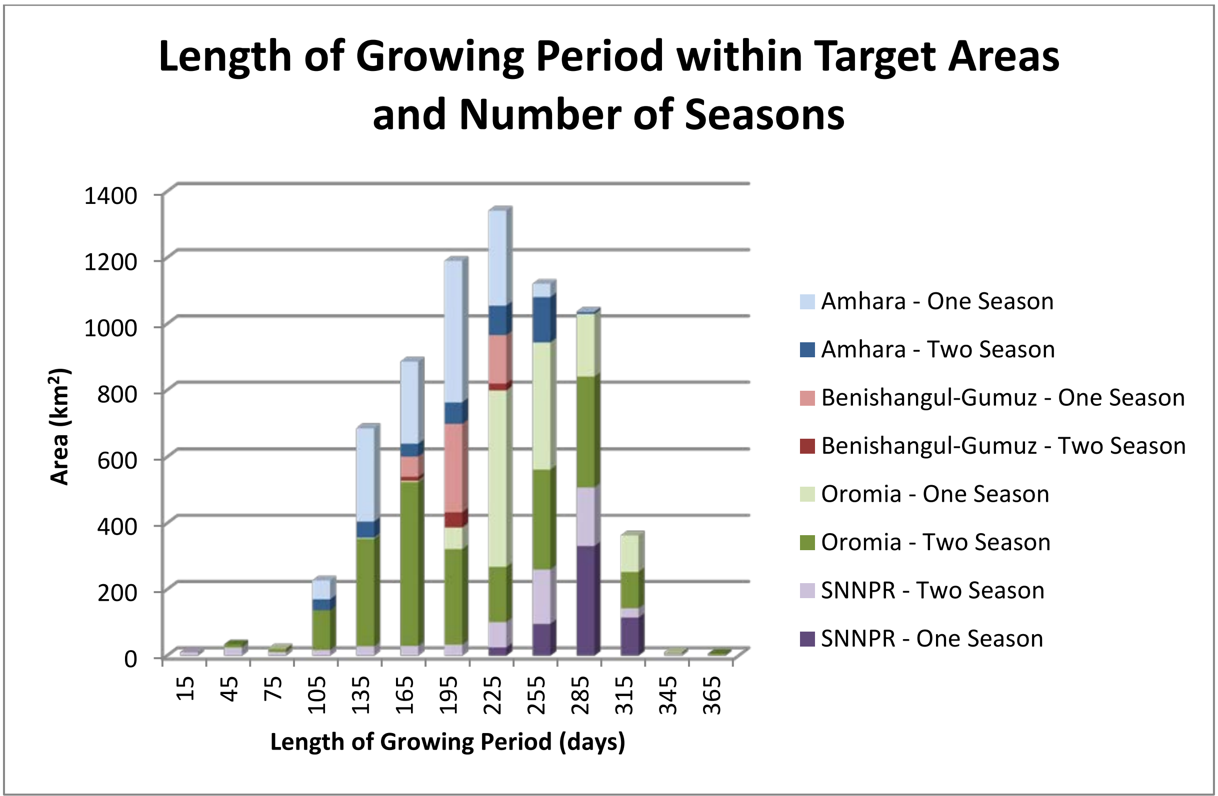


**Figure 4. Seasonality per region in Ethiopia. Source: National Meteorological Agency, 2013**

The length and intensity of each season also differs within each Target Area and allows for different configurations of crops, and different water mangement requirements (Figure 5).

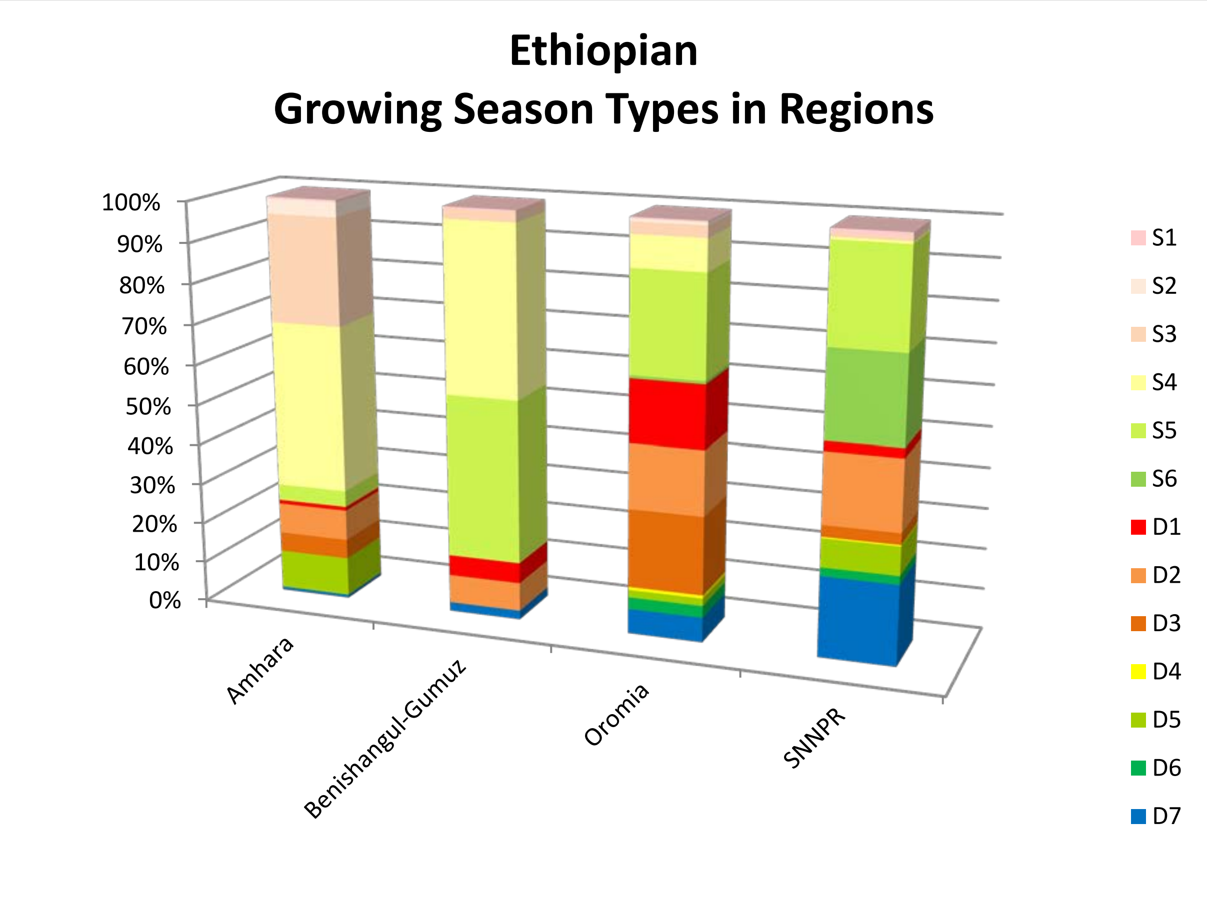


**Figure 5. Growing Period Zones per region in Ethiopia. Source: National Meteorological Agency, 2013**

Where:

**S1**: Single and short growing period, inadequate, supplementary irrigation is needed
**S2**: Single growing period, short, supplementary irrigation is desirable
**S3**: Single growing period, adequate, for short-maturing crops
**S4**: Single growing period, adequate, for crops with medium cycle to maturity
**S5**: Single growing period, adequate for long-maturing crops
**S6**: Single growing period, adequate for long and very long-maturing crops. Less suitable for annual crops
**D1**: Two growing periods, neither is adequate, supplementary irrigation is necessary
**D2**: Two growing periods, neither is adequate, supplementary irrigation is desirable
**D3**: Two growing periods, the first can be considered adequate
**D4**: Two growing periods, both are adequate, for rain-fed crop production in most years, but double cropping is usually unfeasible because of interference between the two growing periods
**D5**: Two growing periods per year, of which both are adequate for crop production in most years. The second growing period is the most important
**D6**: Two growing periods, both are adequate. The first is important
**D7**: Two growing periods, both are adequate; including areas in which the two growing periods merge into a single long growing period

An alternative way of visualising the growing season types is to show the area per region for each of the growing season types, this shows where there is the possibility of testing the same technologies or practices in different zones (Figure 6). For instance the S5 zone has large areas in Benishangul-Gumuz, Oromia and SNNPR which suggests that the same technology could be tested in multiple locations with the same growing period characteristics.

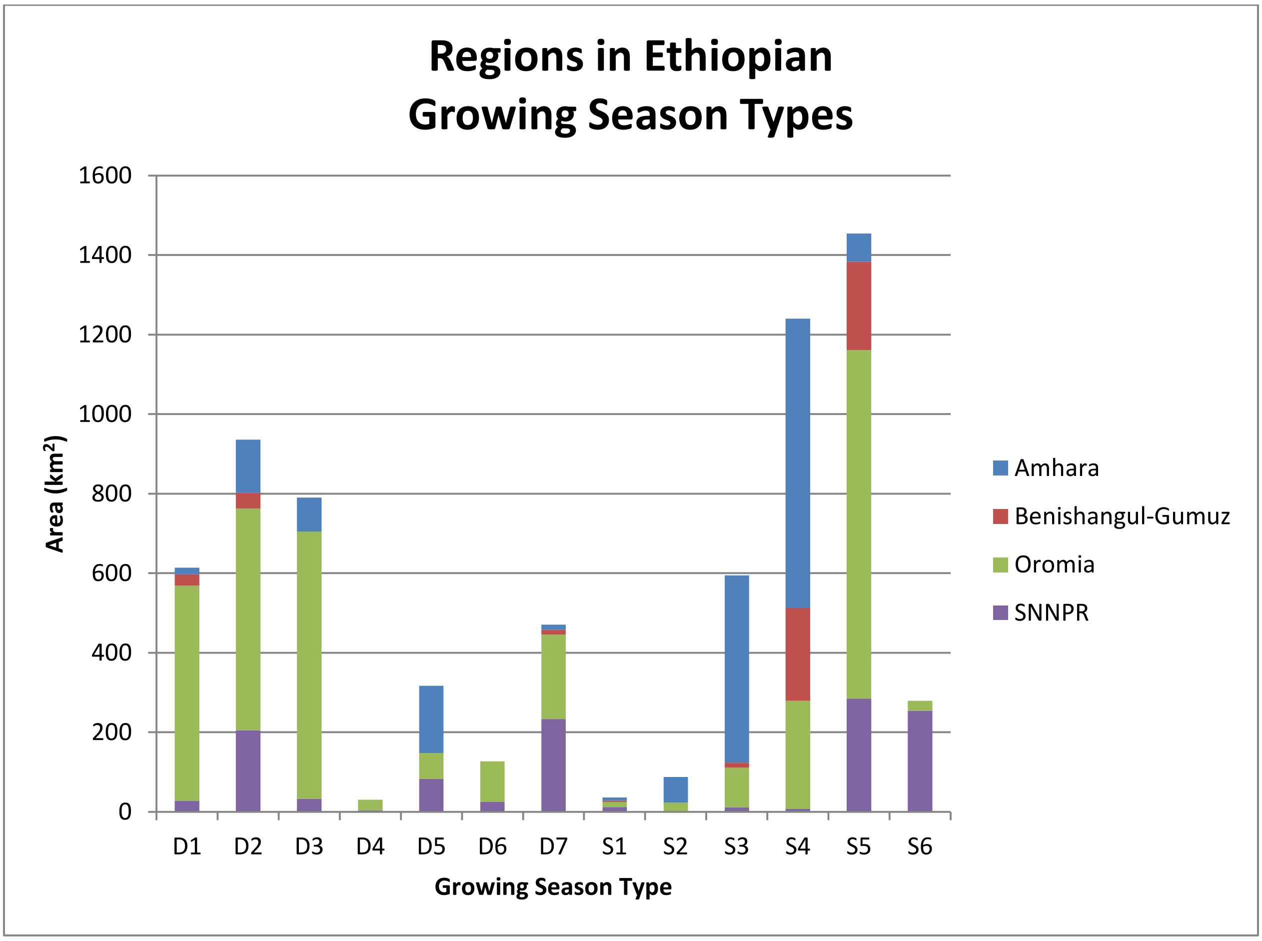


**Figure 6. Regions per Growing Period Zones in Ethiopia. Source: National Meteorological Agency, 2013**

Stratification using the length of growing period is a possibility in Ethiopia and there is potential for testing different LGP zones in multiple regions (Table 5). Nevertheless, it is a decision that needs to be taken in partnership with the researchers in Ethiopia based on the legume varieties that are available and that show promise for yield increases and other useful or preferred traits.

**Table 5. Potential stratification using growing period zones per crop per region**

| Region | Common bean | | | Soybean | | | Chickpea | | | Faba bean | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amhara – centred on Bahir Dar | | | | | | | S4 | S5 | | S4 | S5 |
| Benishangul-Gumuz – centred on Pawe | S4 | S5 | | S4 | S5 | | | | | | |
| Oromia – centred on Debre Zeit | S3 | D4 | | | | | S3 | D4 | | S3 | D4 |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | D3 | D5 | D6 | D3 | D5 | D6 | D3 | D5 | D6 | | |

The growing period zones for the target woredas are less diverse than for the whole region (Table 6) but show that the woredas selected are representative of the regions when areas that are not suitable for N2Africa legumes are excluded (Figure 4).

**Table 6. Growing Period zones per target woreda in each region**

| Region | Target woredas | 'Best bet' legume crop | Growing Period zones | | |
|---|---|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | S4 | | |
| | Bichena | Chickpea | S4 | | |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | S4 | | |
| | Guanga (Guangua) | Soybean, Common bean | S5 | | |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | D4 | | |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | D3 | D5 | S2 |
| | Bakko (Bako Tibe) | Soybean Common bean | S5 | | |
| | Sinana | Faba bean | D3 | D5 | D6 |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | D3 | D5 | |
| | Bodity (Damot Gale) | Chickpea | D5 | S5 | |

## 2.2 Temperature

The traditional agro-ecological belts in Ethiopia are based on altitude and thus to a large extent on temperature, with six belts: Bereha ( < 500m), Kolla (500 – 1,500m), Woina Dega (1,500 – 2,300m), Dega (2,300 - 3,200m), Wurch (3,200 – 3,700m) and Kur ( > 3,700m). The vast majority of the target areas are in the Kolla and Woina Dega agro-ecological belts, although Amhara, SNNPR and Oromia have a significant area in the Dega zone (Figure 7).

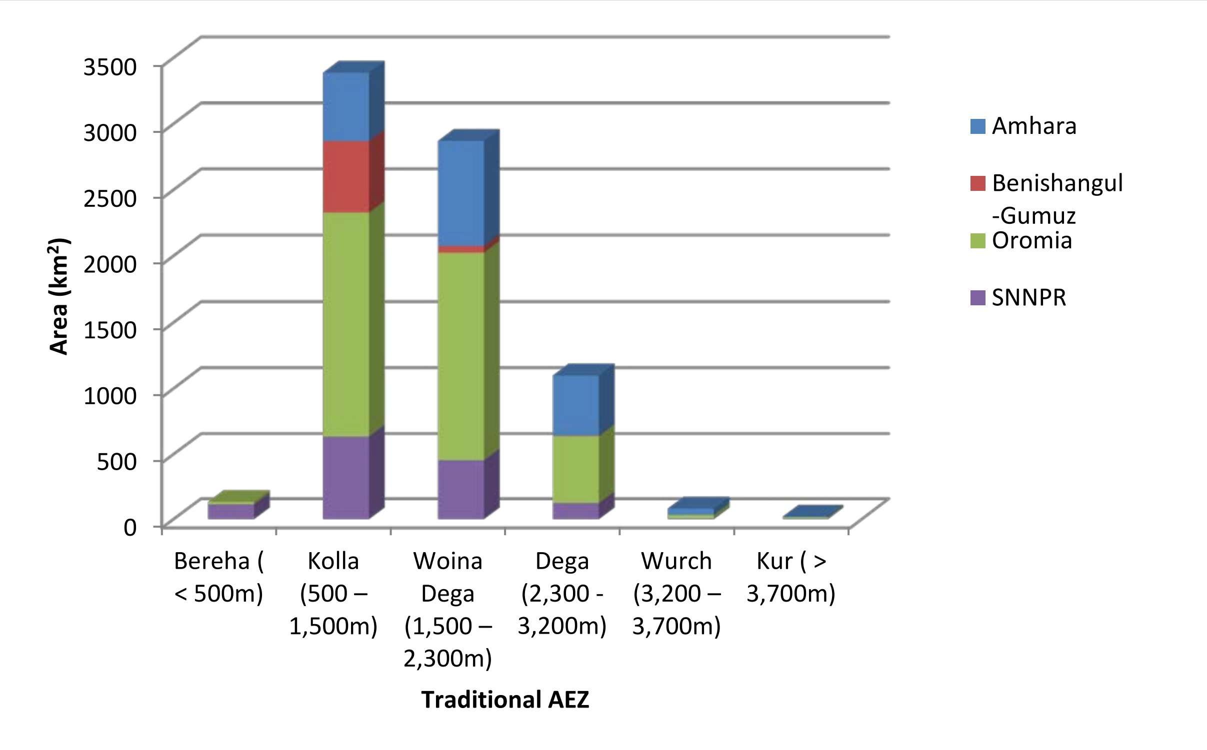


**Figure 7. Regions per traditional agro-ecological Zones in Ethiopia. Source: Author's calculation based on SRTM elevation (Reuter et al., 2007)**

Debre Zeit, Bahir Dar and Hawassa are all in the Woina Dega zone. Within short distances of Debre Zeit and Hawassa are locations in the Kolla and Dega zones, whereas Bahir Dar is distant from the Kolla zone, but closer to the Dega zone. Pawe, like much of Benishangul-Gumuz, is in the Kolla zone but with a few locations nearby in higher elevation zones (Table 7).

**Table 7. Traditional agro-ecological belts per target woreda in each region**

| Region | Target woredas | 'Best bet' legume crop | Traditional agro-ecological belts | | |
|---|---|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | Woina Dega | Dega | Wurch |
| | Bichena | Chickpea | Woina Dega | Dega | |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | Kolla | | |
| | Guanga (Guangua) | Soybean, Common bean | Kolla | Woina Dega | |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | Woina Dega | Dega | |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | Woina Dega | | |
| | Bakko (Bako Tibe) | Soybean Common bean | Woina Dega | | |
| | Sinana | Faba bean | Woina Dega | Dega | Wurch |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | Kolla | Woina Dega | |
| | Bodity (Damot Gale) | Chickpea | Woina Dega | | |

The traditional AEZs are therefore possibly too crude to be used in stratification, and more recently the Agro-ecological zones have been updated to include moisture characteristics in addition to temperature.

## 2.3 Agro-Ecological zones

There are various competing zonation schemes for agro-ecologies in Ethiopia (Hurni, 1998) but the 18 class AEZ developed by the Ethiopian Ministry of Agriculture is the most widely used (Belay Kassie, personal communication, 15th October 2013). This scheme uses both length of growing period and temperature belts, although the temperature classes do not coincide exactly with the elevation classes used in the traditional agro-ecological zones (Table 8).

**Table 8. LGP and temperature classes used in definition of agro-ecological zones in Ethiopia**

| LGP classes | | Temperature classes | |
|---|---|---|---|
| arid | < 45 days | hot | greater than 27°C |
| semi-arid | 46 to 60 days | warm | 21-27.5°C |
| sub-moist | 60 to 120 days | tepid | 16-21°C |
| moist | 120 to 180 days | cool | 11-16°C |
| sub-humid | 180 to 240 days | cold | 7.5-11°C |
| humid | 241 to 300 days | very cold | less than 7.5°C |
| per-humid | greater than 300 days | | |

The six temperature classes are combined to form three temperature belts – hot to warm, tepid to cool and cold to very cold, which are combined with the moisture regimes to define agro-ecological zones in Ethiopia (Table 9).

**Table 9. Definition of agro-ecological zones in Ethiopia**

| **Moisture regimes** | **Temperature regimes** | | |
|---|---|---|---|
| | **Hot to warm (1)** | **Tepid to cool (2)** | **Cold to very cold (3)** |
| **Arid ( A)** | A1 arid hot to warm lowland plains | A2 arid tepid to cool mid highlands | Absent |
| **Semi-arid (SA)** | SA1 semi-arid hot to warm lowlands | SA2 semi-arid tepid to cool mid highlands | Absent |
| **Sub-moist (SM)** | SM1 sub-moist hot to warm lowlands | SM2 sub-moist tepid to cool mid highlands | SM3 sub-moist cold to v. cold sub-afro-alpine to afro-alpine |
| **Moist (M)** | M1 moist hot to warm lowlands | M2 moist tepid to cool mid highlands | M3 moist cold to very cold sub-afro-alpine to afro-alpine |
| **Sub-humid (SH)** | SH1 sub-humid hot to warm lowlands | SH2 sub-humid tepid to cool mid highlands | SH3 sub-humid cold to v. cold sub-afro-alpine to afro-alpine |
| **Humid (H)** | H1 humid hot to warm lowlands | H2 humid tepid to cool mid highlands | H3 humid cold to v. cold sub-afro-alpine to afro-alpine |
| **Per-humid (Ph)** | Ph1 per-humid hot to warm lowlands | Ph2 per-humid tepid to cool mid highlands | Absent |

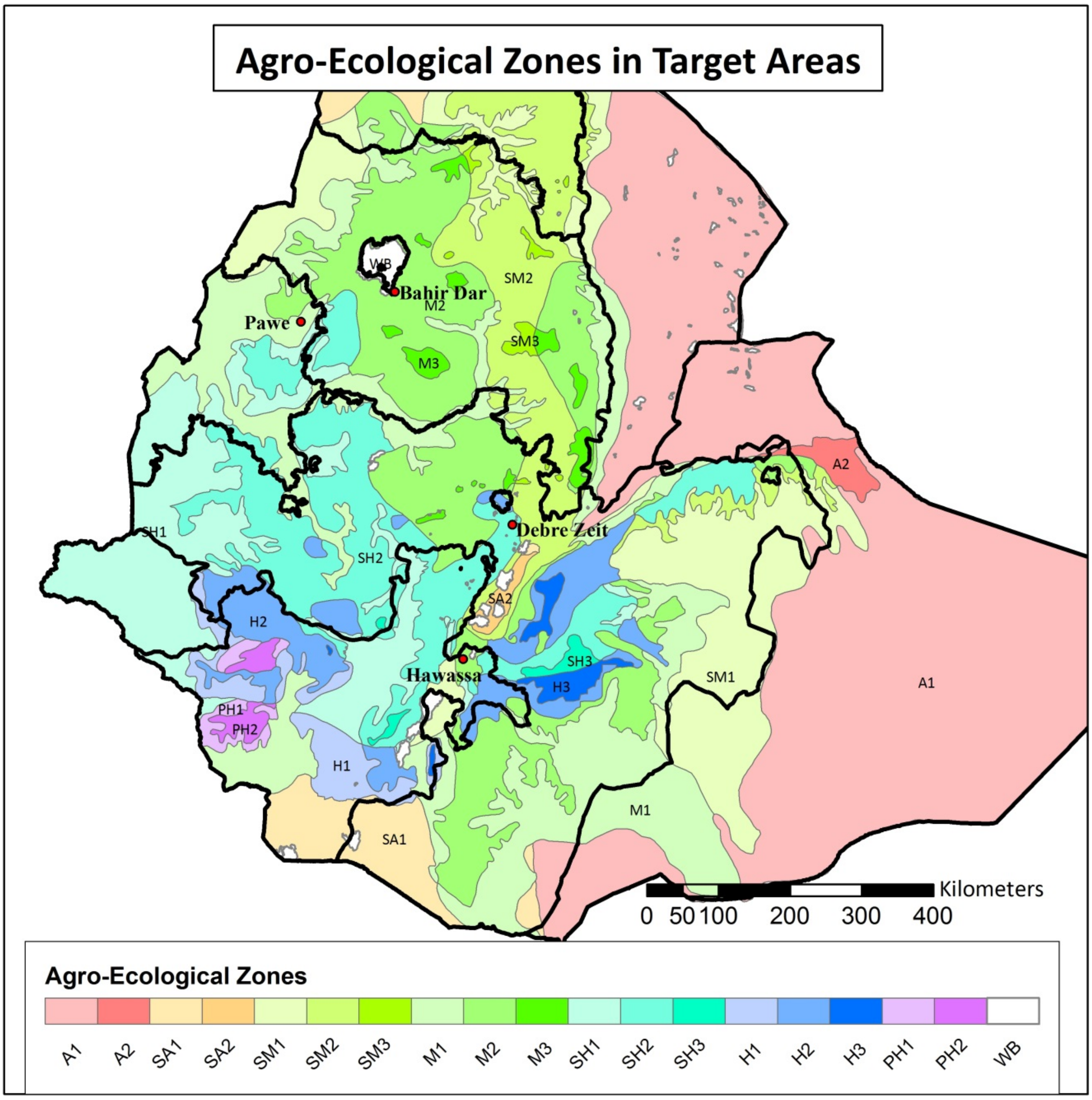


**Figure 8. Agro-ecological zones in Ethiopia. Source: Source: Chamberlin et al., 2007**

The distribution of these agro-ecological zones is not equal among the four target areas (Figure 8), with only four zones (hot to warm moist lowlands, hot to warm sub-humid lowlands, tepid to cool moist mid-highlands, and tepid to cool sub-humid lowlands) present in all four target areas (Figure 9).

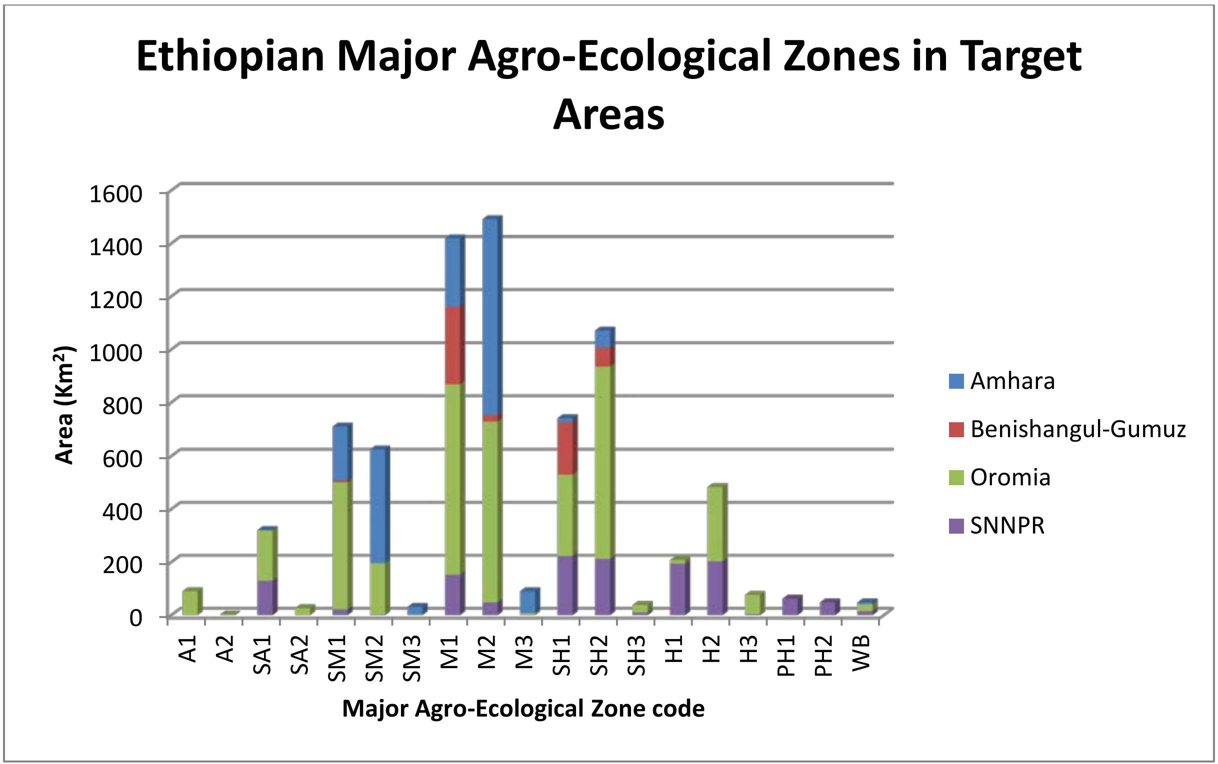


**Figure 9. Regions per agro-ecological Zones in Ethiopia. Source: Author's calculation based on Chamberlin et al., 2007**

The zone surrounding Bahir Dar in Amhara is primarily tepid to cool moist mid-highlands, although within 50 km is a wetter zone of tepid to cool sub-humid mid highlands. The area around Pawe in Benishangul-Gumuz is a mix of tepid to cool moist mid-highlands and hot to warm moist lowlands[1], while Debre Zeit is characterised by tepid to cool sub-humid and sub-moist mid highlands. Hawassa is in the tepid to cool moist mid-highlands although within a short distance of tepid to cool sub-humid and humid mid highlands, and hot to warm sub-moist lowlands. Stratification using the AEZ is therefore a possibility in Ethiopia and there is potential for testing different AEZs in multiple target areas (Table 10).

[1] There are differences in the classification of this zone between datasets and between the Atlas of the Ethiopian Rural Economy – some datasets classify this zone as "Hot to warm sub-moist lowlands".

**Table 10. Potential stratification using agro-ecological zones per crop per region**

| Region | Common bean | | | Soybean | | | Chickpea | | | Faba bean | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amhara – centred on Bahir Dar | | | | | | | M2 | SH2 | | M2 | SH2 |
| Benishangul-Gumuz – centred on Pawe | M1 | M2 | | M1 | M2 | | | | | | |
| Oromia – centred on Debre Zeit | SM2 | SH2 | | | | | SM2 | SH2 | | SM2 | SH2 |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | SM1 | M2 | SH2 | SM1 | M2 | SH2 | SM1 | M2 | SH2 | | |

The target woredas chosen are broadly representative of the agro-ecologies of the regions, and allow the testing of legume crops in diverse agro-ecological zones (Table 11).

**Table 11. Agro-ecological zones per target woreda in each region**

| Region | Target woredas | 'Best bet' legume crop | Agro-ecological zones | | |
|---|---|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | SM2 | M2 | M3 |
| | Bichena | Chickpea | M2 | M3 | |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | M1 | SH1 | |
| | Guanga (Guangua) | Soybean, Common bean | SH1 | SH2 | |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | SM2 | SH2 | H2 |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | SA2 | SM2 | M2 |
| | Bakko (Bako Tibe) | Soybean Common bean | M2 | SH2 | |
| | Sinana | Faba bean | M2 | SH2 | H2 |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | SM1 | M2 | |
| | Bodity (Damot Gale) | Chickpea | SH2 | | |

## 2.4 Soils

Soils are an important component of the environment that affects biological nitrogen fixation via the performance of the legume crop and the performance of the rhizobia.. With sufficient information soils can be classified and introduced into the research design in Ethiopia but it is clear that many functional soil properties can change markedly over small distances; this makes mapping at the national scale less useful. Some functional soil properties, such as low pH soils, may be more homogenous over short distances and are thus easier to map and use in stratification.

Maps of major soil type are available and while there is a relationship between the soil type and functional soil characteristics – such as the low pH of the nitosols or poor drainage of the vertisols – the local modification or the effects of terrain may override the general influence of these soil types.

## 2.5 Cropping systems

The biophysical relevance of a technology is not limited to the suitability of a particular location in terms of potential yield or to the constraints that contribute to a yield gap. Legumes often occupy niches in the farm system which are often defined by the relationship with the other crops and livestock activities.

Livelihood zones incorporate not only the major environmental characteristics but also the exploitation of these resources for agriculture. Zones have been characterised for all of Ethiopia at a fairly broad scale, and are described by the major crops which are part of the livelihood strategies in those areas or by the general agro-ecology (MoARD, 2011). Livelihood activities are also captured for the zones in three regions (Amhara, Tigray and SNNPR) and allow for a more detailed analysis of key crops or pastoral strategies, and offer some *a priori* guidance on the areas that are already growing the N2Africa legumes.

Most of the livelihood zones are characterised by the cereal crops that dominate production, but some zones, such as Becho-Adea and Selale-Ambo include legumes as major livelihood activities (Table 12). Stratification using the livelihood zones is problematic given the lack of an objective function and the diversity of farm livelihood strategies. Instead the information in the livelihood profiles can be used to guide the choice of implementation sites within the woredas and potentially for guiding the choice of villages for the baseline survey.

**Table 12. Livelihood zones per target woreda in each region**

| Region | Target woredas | 'Best bet' legume crop | Livelihood Zone | Reference to legumes |
|---|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | North East Woyna Dega Mixed Cereal<br><br>Guna Highland Barley and Potato | Faba bean, lentils and oil seeds are mentioned as cash crops<br><br>Faba beans are mentioned as cash crops |
| | Bichena | Chickpea | South West Woyna Dega Teff | 'beans' produced by better-off farmers |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | Central Kolla Sorghum, Maize & Millet | Groundnut is mentioned |
| | Guanga (Guangua) | Soybean, Common bean | South West Maize, Finger Millet and Teff productive | Lentils produced by middle and better-off farmers |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | Becho-Adea Teff & Chickpea | Chickpeas are mentioned as cash crops. Lentils and faba beans produced by middle and better-off farmers |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | Abijata Shala Jido Agro-Pastoral<br><br>Rift Valley Maize & Haricot Bean | Common beans are mentioned as cash crops<br><br>Common beans are mentioned as cash crops |
| | Bakko (Bako Tibe) | Soybean Common bean | Gibe Maize & Peppers<br><br>Ambo Selale Ginderberet Teff & Wheat<br><br>Selale-Ambo Highland Barley, Wheat and Horsebean belt | No report<br><br>Faba beans are mentioned<br><br>No report but Faba beans are mentioned in name |
| | Sinana | Faba bean | Arsi Bale Wheat, Barley & Potato | Pulses are mentioned |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | Bilate Basin Agro-Pastoral LZ<br><br>Sidama Maize Belt LZ | Common beans are mentioned as food crops<br><br>Common beans are mentioned as food crops |
| | Bodity (Damot Gale) | Chickpea | Wolayita Maize and Root Crop LZ<br><br>Wolayita Barley and Wheat LZ | Common beans are mentioned as food crops<br><br>Common beans, faba beans and peas are mentioned as cash and food crops |

Another source of data on cropping systems is available from the Atlas of common bean in Africa (CIAT, unpublished). This is a compilation of expert knowledge and refers to specific bean production areas in various countries. In Ethiopia there are ten different bean production areas, mainly concentrated in Oromia and SNNPR. Information was collected on the cropping systems of common beans, and the main intercrop. Noticeable is the diversity of systems in SNNPR and the prevalence of maize intercrops in all of the production areas (Table 13).

**Table 13. Common bean cropping systems per target woreda in each region**

| **Region** | **Target woredas** | **'Best bet' legume crop** | **Dominant cropping system for common beans** |
|---|---|---|---|
| Amhara – centred on Bahir Dar | Farta | Faba Bean | No Data |
| | Bichena | Chickpea | No Data |
| Benishangul-Gumuz – centred on Pawe | Pawe | Soybean, Common bean | Sole crop<br><br>Maize intercrop |
| | Guanga (Guangua) | Soybean, Common bean | Sole crop<br><br>Maize intercrop |
| Oromia – centred on Debre Zeit | Akaki | Chickpea | Sole crop<br><br>Maize intercrop |
| | Adje or Aje (in Shalla / Siraro woreda west Arsi) | Common bean | Sole crop<br><br>Maize intercrop |
| | Bakko (Bako Tibe) | Soybean Common bean | Maize intercrop<br><br>Sole crop<br><br>Sorghum intercrop |
| | Sinana | Faba bean | No Data |
| Southern Nations, Nationalities and Peoples Republic – centred on Hawassa | Borcha (Boricha) | Common bean | Roots and Tubers intercrop<br><br>Maize intercrop<br><br>Coffee intercrop<br><br>Sole crop |
| | Bodity (Damot Gale) | Chickpea | Roots and Tubers intercrop<br><br>Maize intercrop<br><br>Coffee intercrop<br><br>Sole crop |

## 2.6 Stratification according to biophysical relevance of the legume technology

The characterisation of Ethiopia according to the key biophysical variables suggests that stratification using agro-climatic variables is unlikely to change the broad target areas and the choice of legumes but remains a useful tool for communicating the rationale behind those decisions and allows the identification of areas with similar biophysical contexts.

The length of growing period is a common indicator of agro-ecological potential and in East Africa a threshold of 200 days has been used to differentiate areas with higher and lower agro-ecological potential (ASARECA, 2005). The poor spatial resolution of the LGP compared to the agro-ecological zones means that latter can be used to stratify the country based on moisture regimes (Chamberlin et al., 2006) while retaining well understood boundaries (Figure 10). Reliable moisture areas are those agro-ecological zones with LGP greater than 180 days, i.e. sub-humid to per-humid (Table 8).

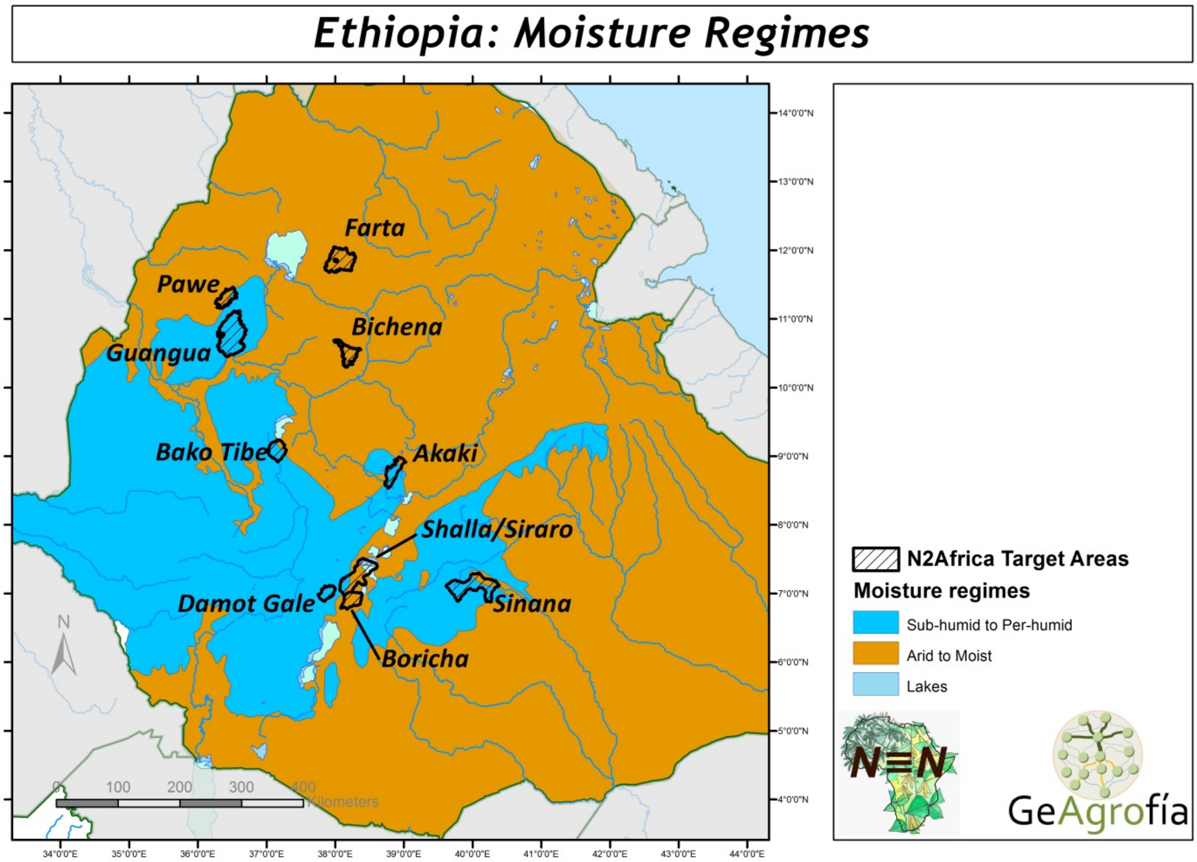


**Figure 10. Humid and Dry moisture regimes in Ethiopia. Source: Chamberlin et al., 2007**

The result of stratifying Ethiopia based on the average temperature of the wettest quarter of the year is that the highland districts of the rift valley and Amhara are classified as dry and the other districts as humid (Table 14).

**Table 14. Stratification of target woredas according to the moisture regime in Ethiopia**

| Humid | Dry |
|---|---|
| Damot Gale, Akaki, Sinana, Guangua, Bako Tibe | Farta, Bichena, Shalla/Siraro, Boricha, Pawe |

# 3 Land availability, quality or tenure

Availability of land, its quality and continued access to land was shown to be a major constraint to or a factor affecting the adoption of legumes in Africa (Farrow, 2014). Land availability, quality and tenure are factors in the adoption of legumes which are experienced at the household level but which are affected by drivers at multiple levels – such as historical customary tenure systems, local bylaws on grazing rights, and migration policies. Stratifying sites is therefore difficult unless proxies can be found at the national level. One proxy for land availability is the population density, which is associated with pressure on land in many areas of Ethiopia (MoARD, 2011).

## 3.1 Population density

In Ethiopia data are available at the woreda level for total population, population density, and dependency ratios (a driver of future land availability), but are from 2002 (Figure 11).

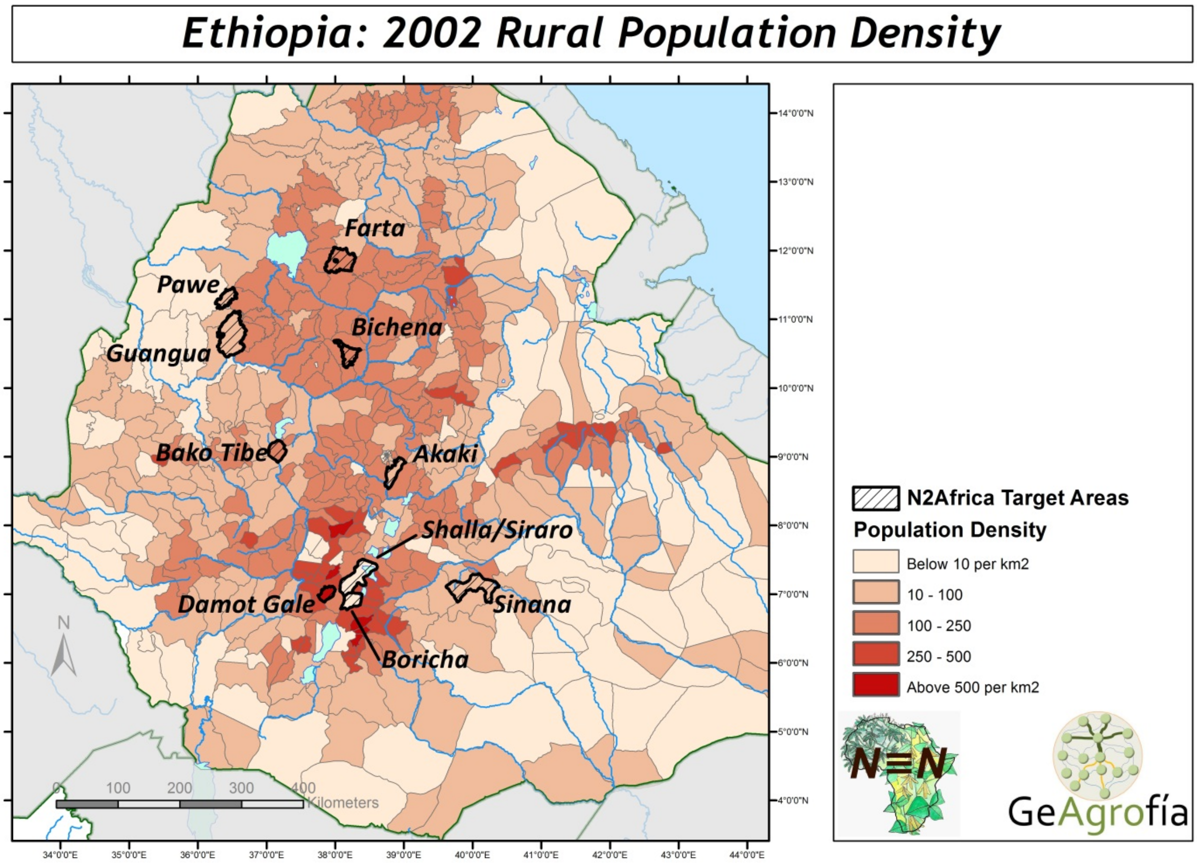


**Figure 11. 2002 Rural population density in Ethiopia. Source: Chamberlin, 2007**

Two different sources of spatially explicit data for population density from the 2006 and 2010 are also available and display the intra-district differences in population density. These maps show generally similar patterns of population density in the target districts in Ethiopia, although differences between the datasets are apparent due to the methodologies used in their creation (Figure 12 and Figure 13). The most appropriate source is from 2010, which combines woreda level population densities as well as some modelling to distribute the population.

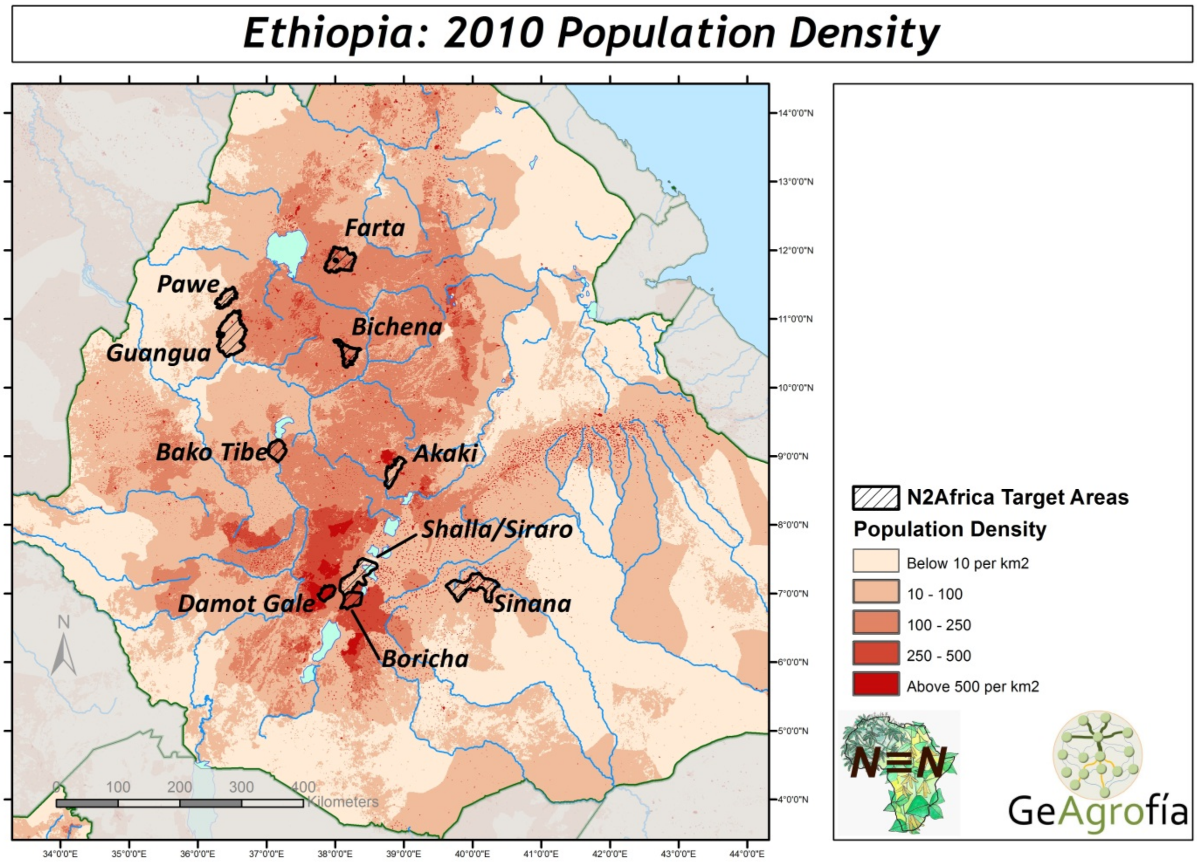


**Figure 12. 2010 Population density in Ethiopia. Source: AfriPop 2010 (Linard et al., 2010)**

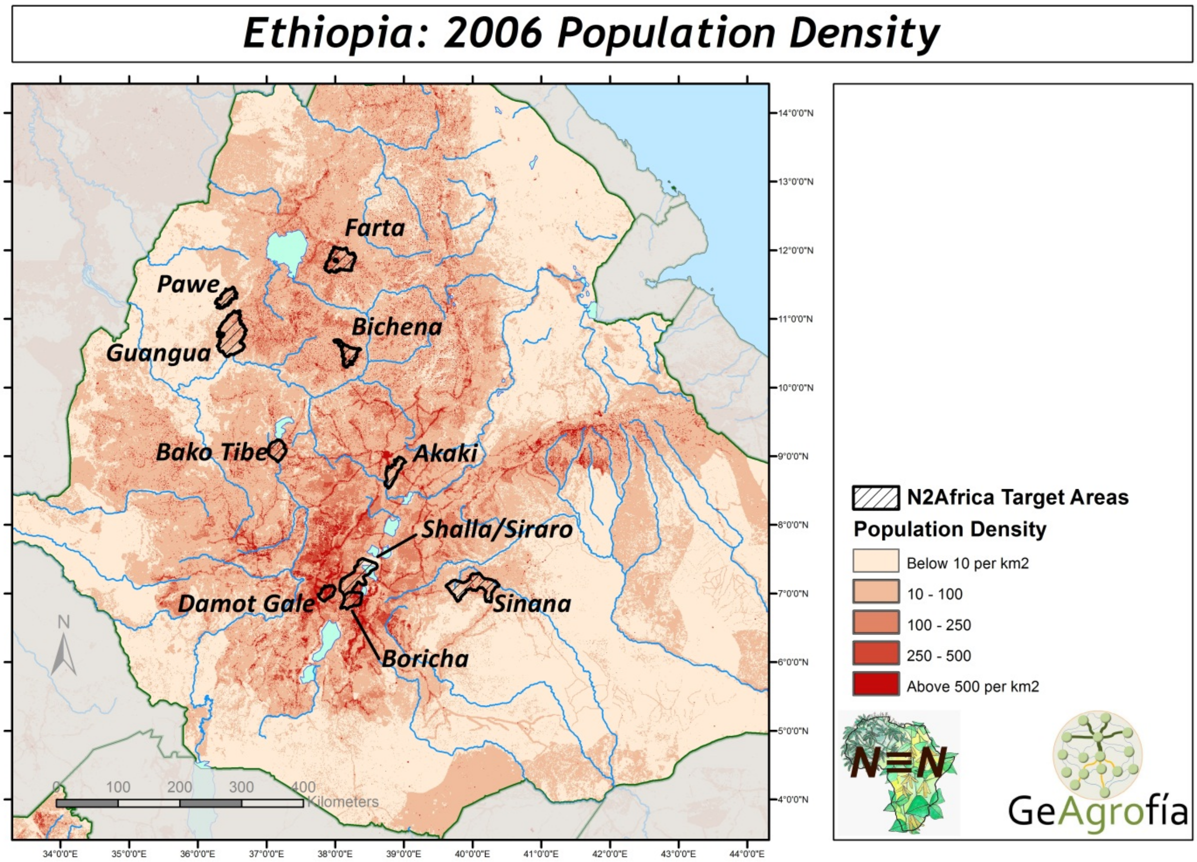


**Figure 13. 2006 Population density in Ethiopia. Source: LandScan2006 (Bright et al., 2007)**

## 3.2 Stratification according to land availability, quality or tenure

Ruecker et al., (2003) use a density of 100 persons per km$^2$ which allows discrimination between and within districts in the target area and shows clearly those areas where land availability is an issue (Figure 14).

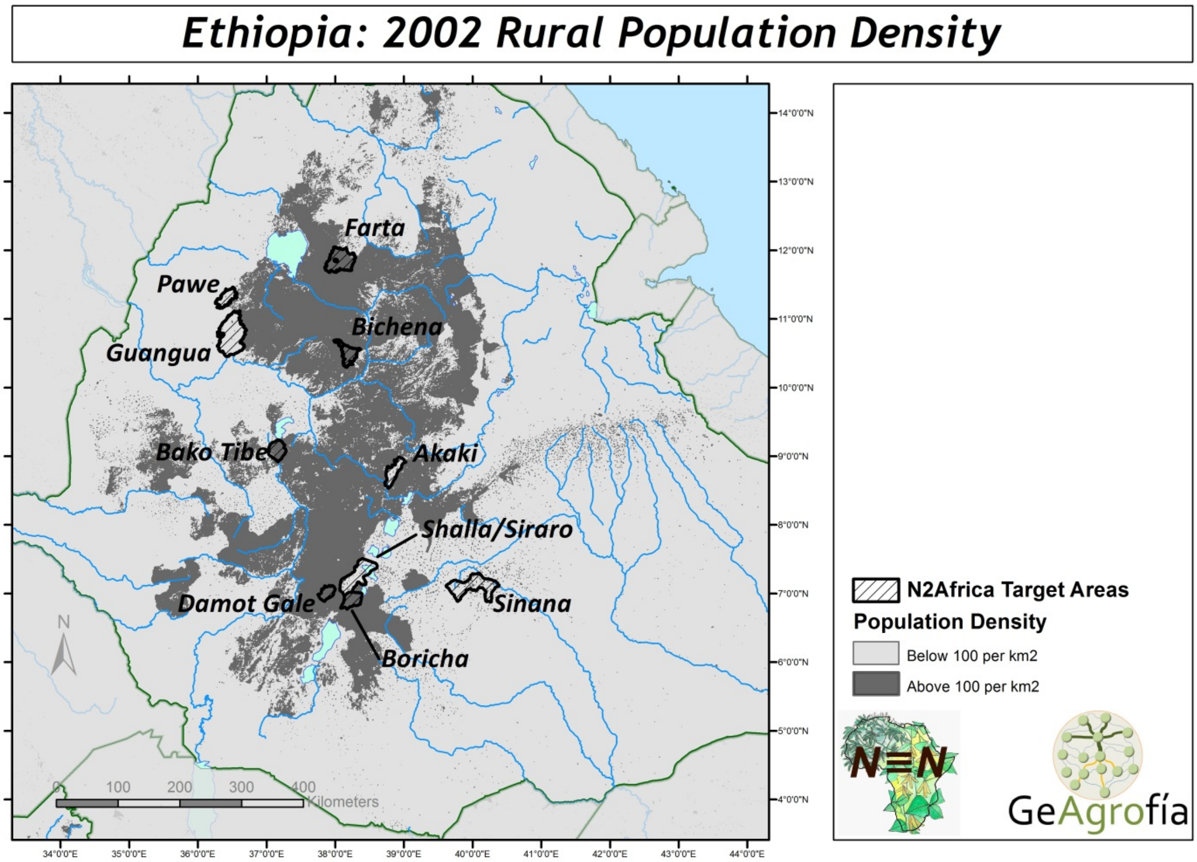


**Figure 14. Population density threshold applied in Ethiopia**

The result of stratifying Ethiopia based on population density and farm size is that the woredas in Benishangul-Gumuz and two out of the three woredas in Oromia are classified as low density whereas the woredas in Amhara and SNNPR districts are classified as high density (Table 15).

**Table 15. Stratification of target woredas according to population density in Ethiopia**

| High Population density | Lower Population density |
|---|---|
| Damot Gale, Bako Tibe, Farta, Bichena and Boricha | Shalla/Siraro, Pawe Akaki, Sinana, and Guangua, |

# 4 Output market for agricultural (legume) products

Access to markets for grain legumes is seen as a pre-requisite for increasing the adoption of improved legume varieties, inputs and practices that can increase productivity. Successful engagement with markets has many components including access to information, and the ability to meet market demands for quality and quantity. Some of these factors are dynamic, or are not dependent on location and are therefore difficult to incorporate into a stratification scheme, however physical access to markets is an important pre-requisite for successful engagement with output markets and can be mapped or modeled (e.g. Deichmann, 1997; Geurs et al., 2001) and used to stratify regions into areas with poor and good access (Ruecker et al., 2003; ASARECA, 2005).

The general method for modelling access to markets follows Farrow et al. (2011; 2013) in a raster environment using a 'costdistance' algorithm (Esri, 2012) that calculates the shortest weighted distance to the nearest market across a friction surface; the surface is composed of roads, land cover and barriers to movement (Appendix 1) and is modified by slope which is treated in the same way as in Nelson (2008).

Market access is assumed to be determined by the time required to reach a market location with thresholds representing the limits of acceptable proximity (Church and ReVelle, 1974). Different time thresholds are applied (Table 14) according to the attractiveness or importance of the market (Reilly, 1931). Each market type was modelled separately and the results combined to give a binary map showing good and poor market access areas (Figure 15, Figure 16, Figure 17, Figure 18).

**Table 16. Time threshold to reach different market types**

| Market importance | Threshold (hours) |
|---|---|
| Most important market | 8 |
| Next important market | 6 |
| Less important market | 4 |
| Least important market | 1 |

The importance of markets for the three grain legume crops being tested in Ethiopia can be indicated by the volume of trade at different market centres, but as these data are not available for all crops expert knowledge has been used (Wolde-Meskel, personal communication 24th November 2013). The market centres for common beans were extracted from information from the Atlas of Common bean in Africa (CIAT, unpublished) but were modified by partners from N2Africa (Table 19).

**Table 17. Markets per legume crop according to different market types in Ethiopia**

| Market importance | Common bean | Soybean | Chickpea | Faba bean |
|---|---|---|---|---|
| Most important markets | Nazareth/Adama, Addis Ababa, Shashemene, Kenya, Hawassa | Chagni, Addis Ababa | Arba-minch, Dilla, Wolayita Sodo, Addis Ababa, North Gonder, Humera, Metema, Bahir Dar | Addis Ababa , Assela, Nazreth, Debrezeit, Ambo, Jeldu, Holetta, Adisalem, Gondar , Metema – Sudan, Wolikite, Desse, Bahir Dar, Debire birhan |
| Next important markets | Mota/Enemay, Chiro, Desse/Kombolcha, Showrobit, Chagni, Sodo, Welkite, Nejo, Metu, Bahir Dar, Debre Markos, Finoteselam, Gambela | | Shashemene, Hawassa | Hawassa, Shashemene |
| Less important markets | Ziwaye, Nifas Mewcha, Hirna, Debre berham, Injibara, Durame/Halaba, Butajira, Dembidolo, Nekemite | | Desse/Kombolcha | Addadi-Mariam, Melon, Soddo, Aleta Wondo, Dilla |
| Least important markets | Meki/Alemtena, Mechara, Asosa, Tercha, Werabe, Mendi, Jimma | Kosober | Woldia, Debrebrihan | |

The model outputs show that central Ethiopia has generally good access to markets for all four crops, due in part to the proximity to Addis Ababa or to the main trading corridor towards the border with Djibouti. Differences between the districts in target areas are noticeable for common bean where Guangua and parts of Bako Tibe have poorer market access than the districts around Hawassa (Figure 15). For the soybean target area there is a big difference within the district of Guangua with only northern areas experiencing good market access (Figure 16). The situation for chickpea shows that all three woredas have good access to markets (Figure 17), whereas for faba bean the district of Farta has generally good access while Sinana only has good access close to the main road which passes through the centre of the woreda (Figure 18).

Stratification based on market access (Table 18) can therefore help in both differentiating among woredas and can be used to orient the location of some N2Africa activities, such as the baseline survey which will provide further information on market integration of smallholder farmers.

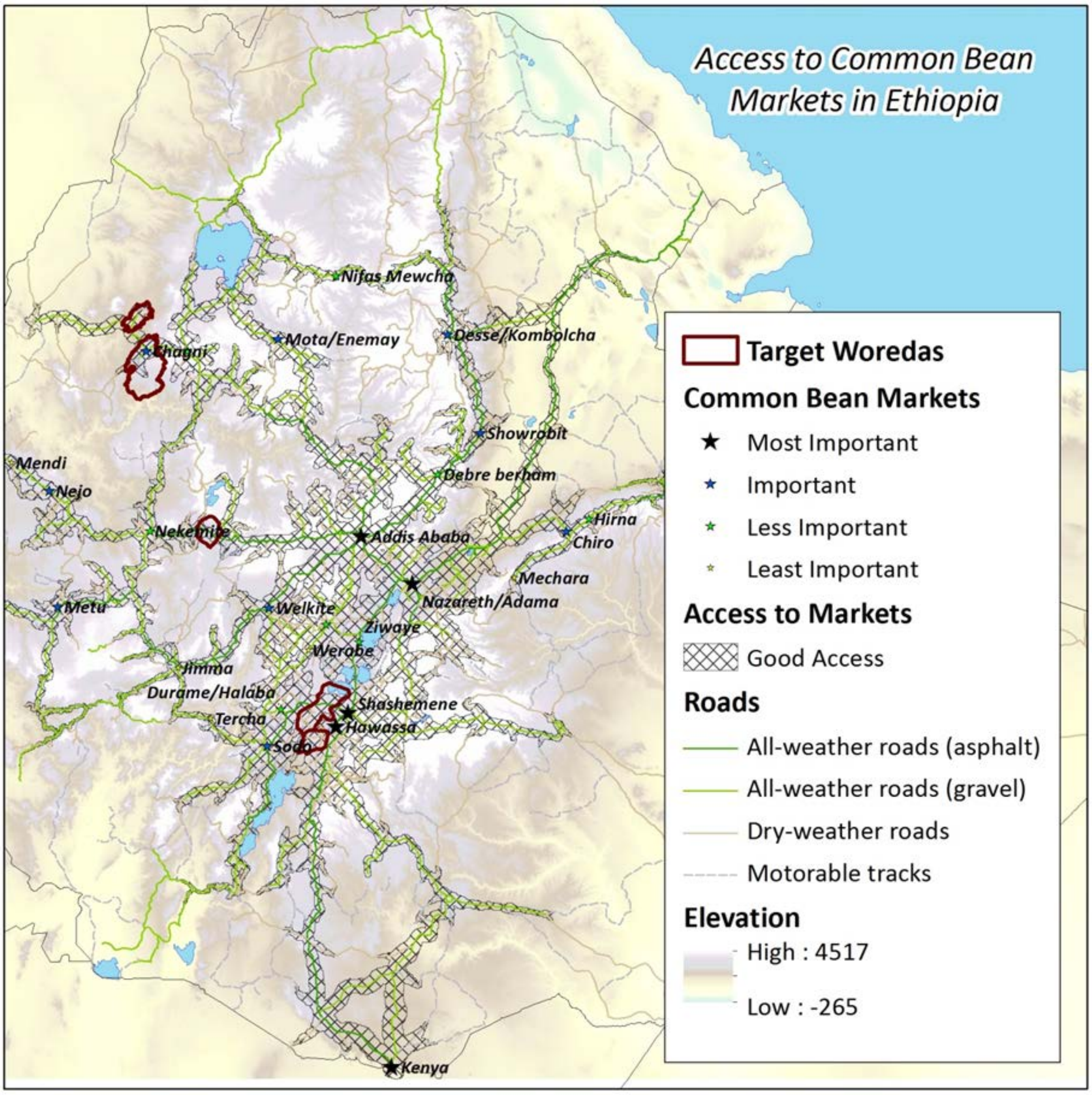


**Figure 15. Access to common bean markets in Ethiopia**

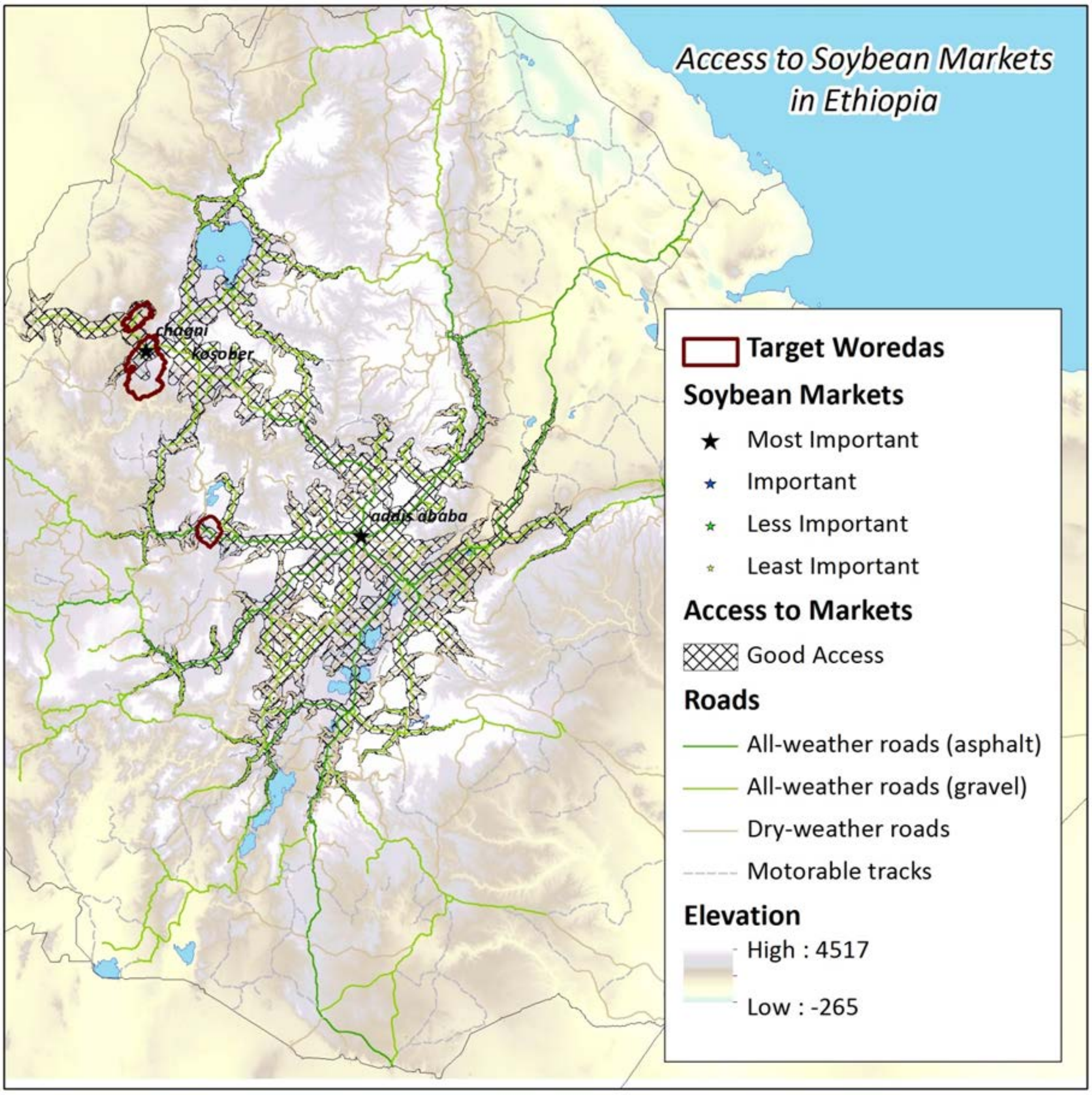


**Figure 16. Access to soybean markets in Ethiopia**

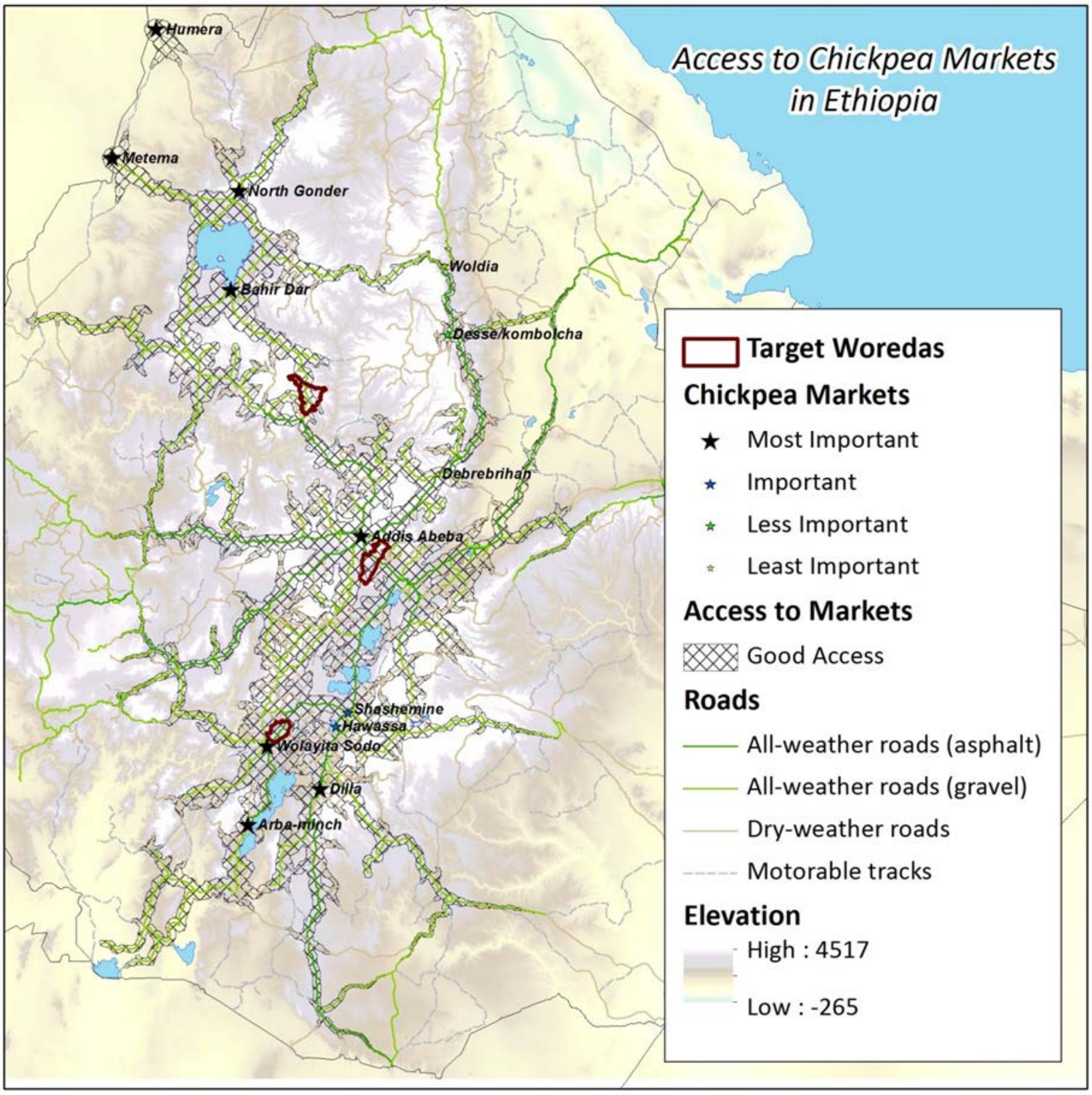


**Figure 17. Access to chickpea markets in Ethiopia**

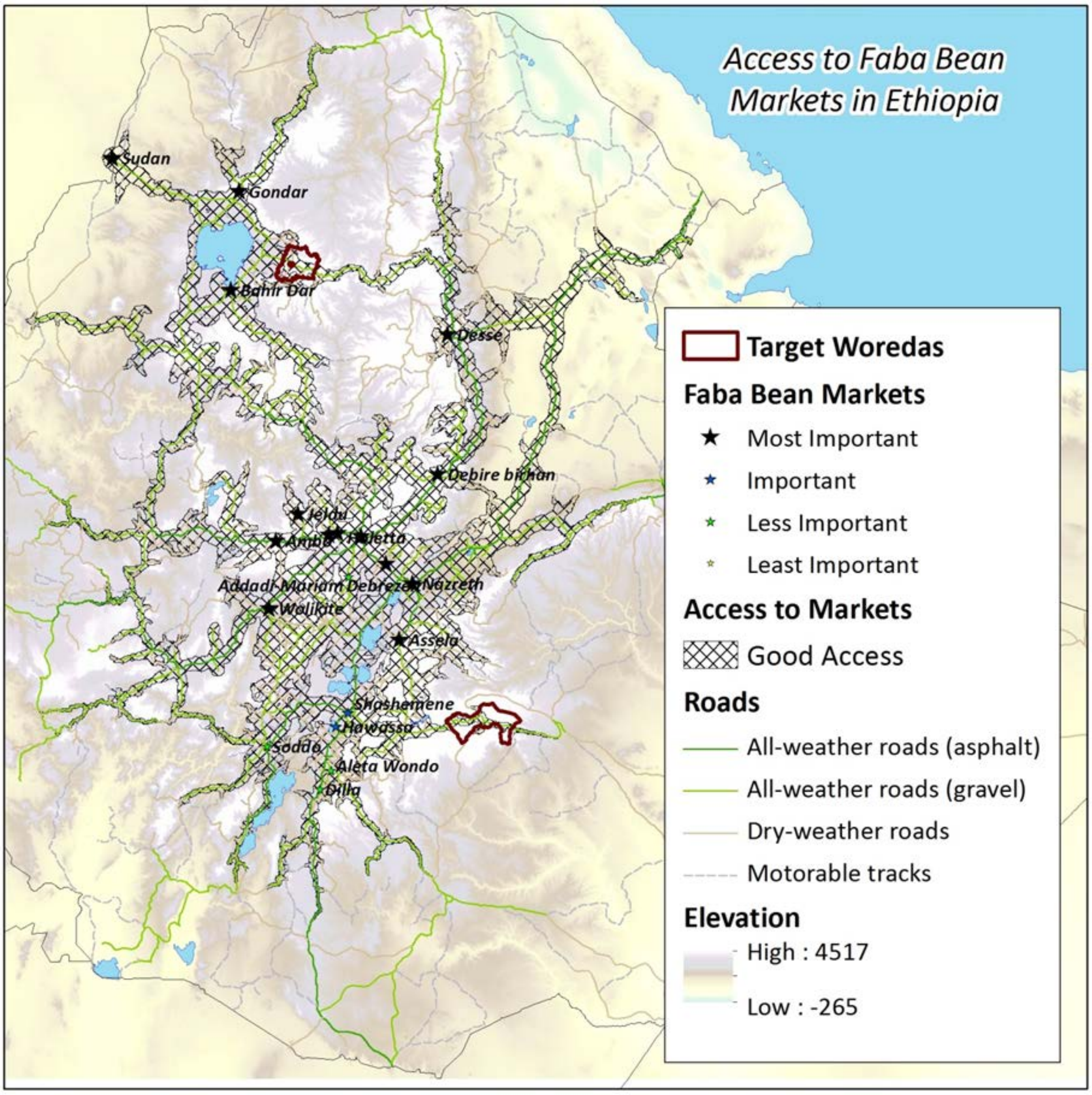


**Figure 18. Access to faba bean markets in Ethiopia**

**Table 18. Stratification of target woredas according to market access in Ethiopia**

| Good market access | Poor market access |
|---|---|
| Farta, Bichena, Pawe, Akaki, Shalla/Siraro, Boricha, Damot Gale | Guangua, Sinana, and parts of Bako Tibe |

# 5 Adoption domains

**I construct domains based on the binary stratification of moisture (**

Table 14), population density (Table 15) and market access (Table 18). These three variables are considered as factors rather than constraints (Conchedda et al., 2001) and I do not describe suitability of any particular technology *per se*. Instead I combine the variables and create domains (Weber et al., 1996; Okike et al., 2000; ASARECA, 2005; Notenbaert et al., 2013; Homann-Kee Tui, et al., 2013) that have implications on the treatments and interventions (Kristjanson, et al., 2002) that will lead to the adoption of grain legumes.

When the three variables are combined there are eight possible domains (Table 19), these domains are unlikely to be equally representative of either the rural population or the land area due to the deliberate choice of thresholds for the three variables, but instead represent niches in which the legume technologies need to fit.

**Table 19. Possible adoption domains based on binary stratification of key variables**

| | | Short growing period | Long growing period |
|---|---|---|---|
| Good Market Access | High Population Density | **1** | **2** |
| | Low Population Density | **3** | **4** |
| Poor Market Access | High Population Density | **5** | **6** |
| | Low Population Density | **7** | **8** |

Domains are constructed separately for each crop due (Figure 19, Figure 20, Figure 21 and Figure 22) to the different market access maps and the target districts are characterised using the adoption domain for the appropriate legume crop (e.g. Farta is characterised using the faba bean adoption domain).

The results (Figure 23) show that all of the domains are encountered in the target woredas and that testing different crops among the woredas is possible using these domains, with each crop able to be tested in at least five domains. The woredas with the most diversity of domains are Akaki and Shalla/Siraro, which implies that site selection within these districts must be undertaken with great care, but that these districts offer opportunities for multiple niches to be considered. In contrast Damot Gale is characterised by a single domain which implies that site selection within this woreda is less important.

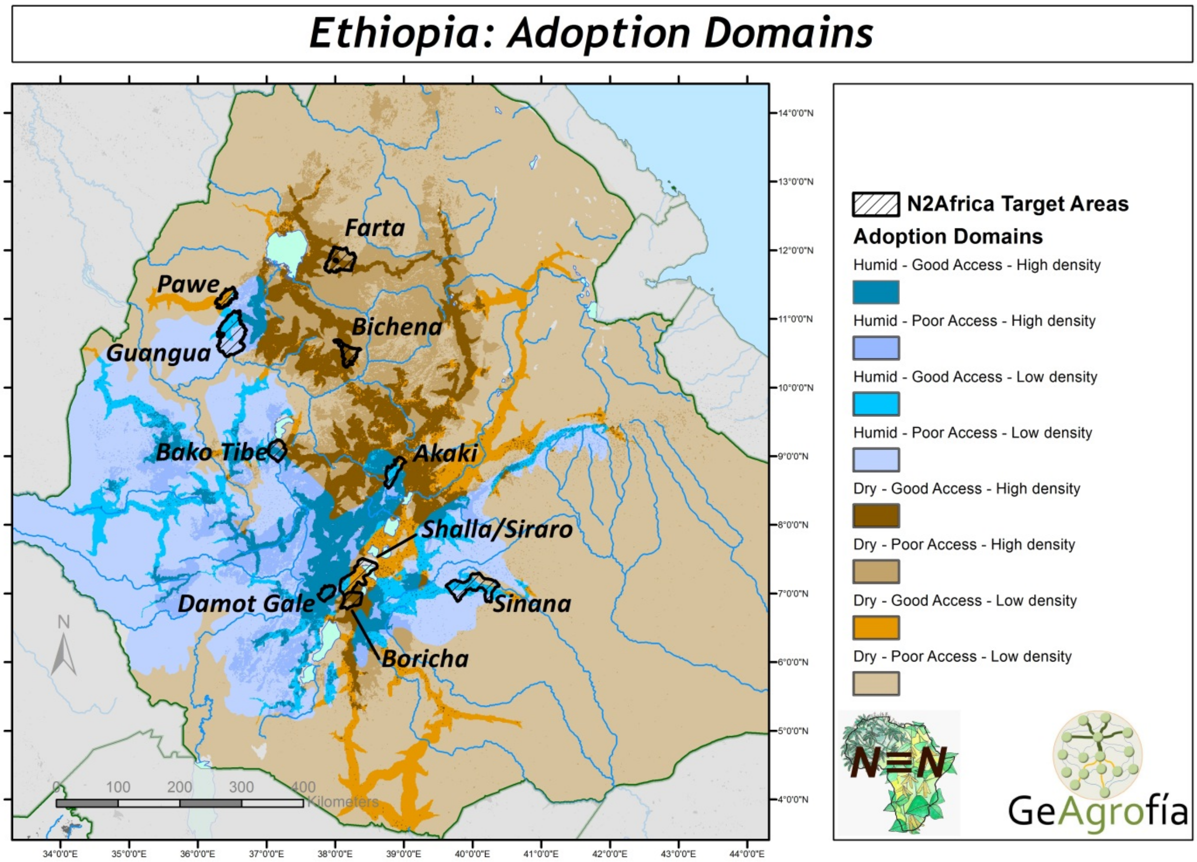


**Figure 19. Common bean adoption domains**

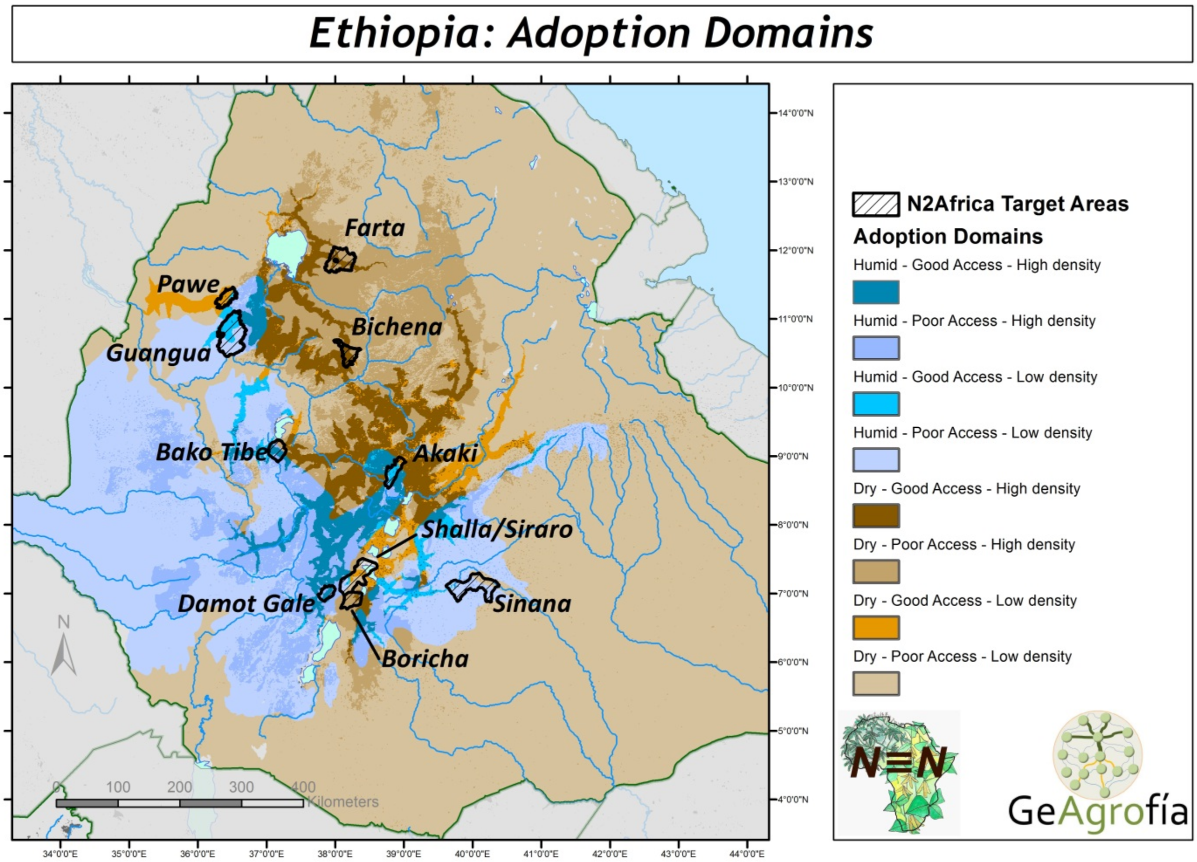


**Figure 20. Soybean adoption domains**

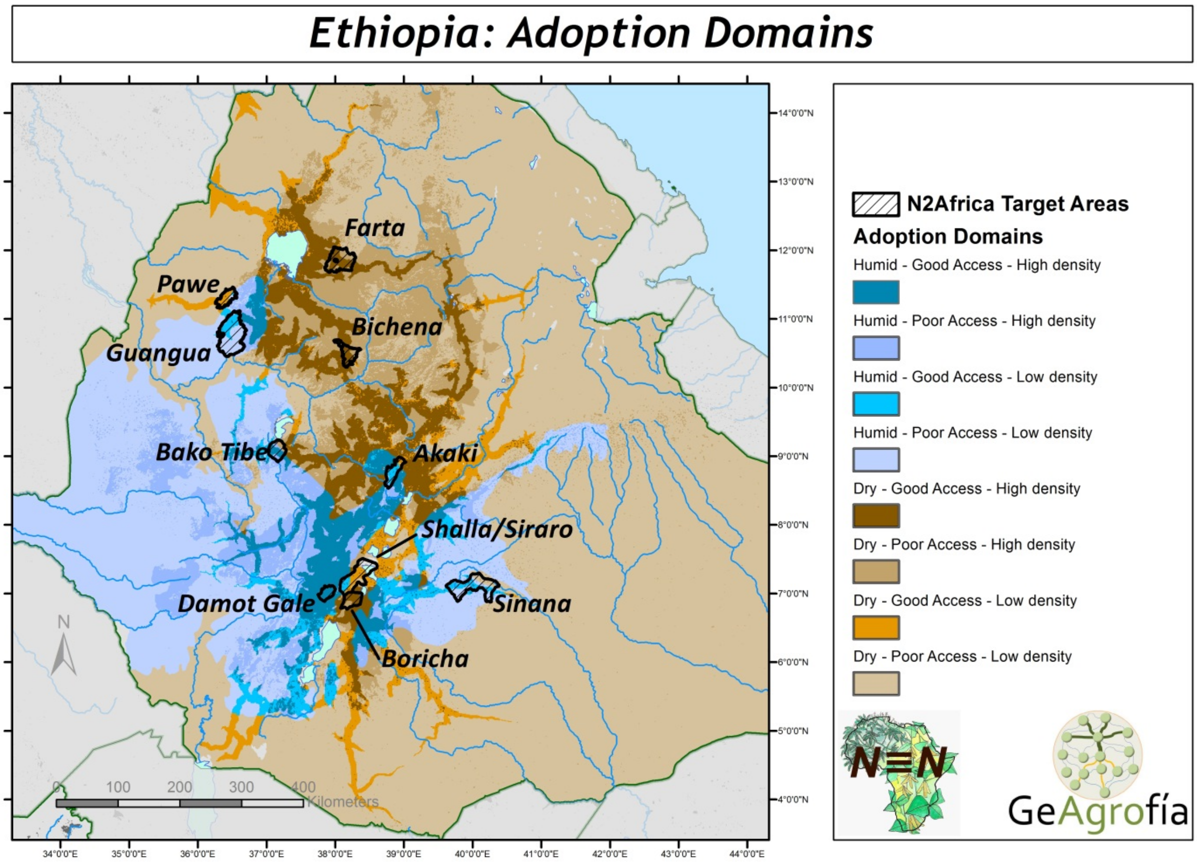


**Figure 21. Chickpea adoption domains**

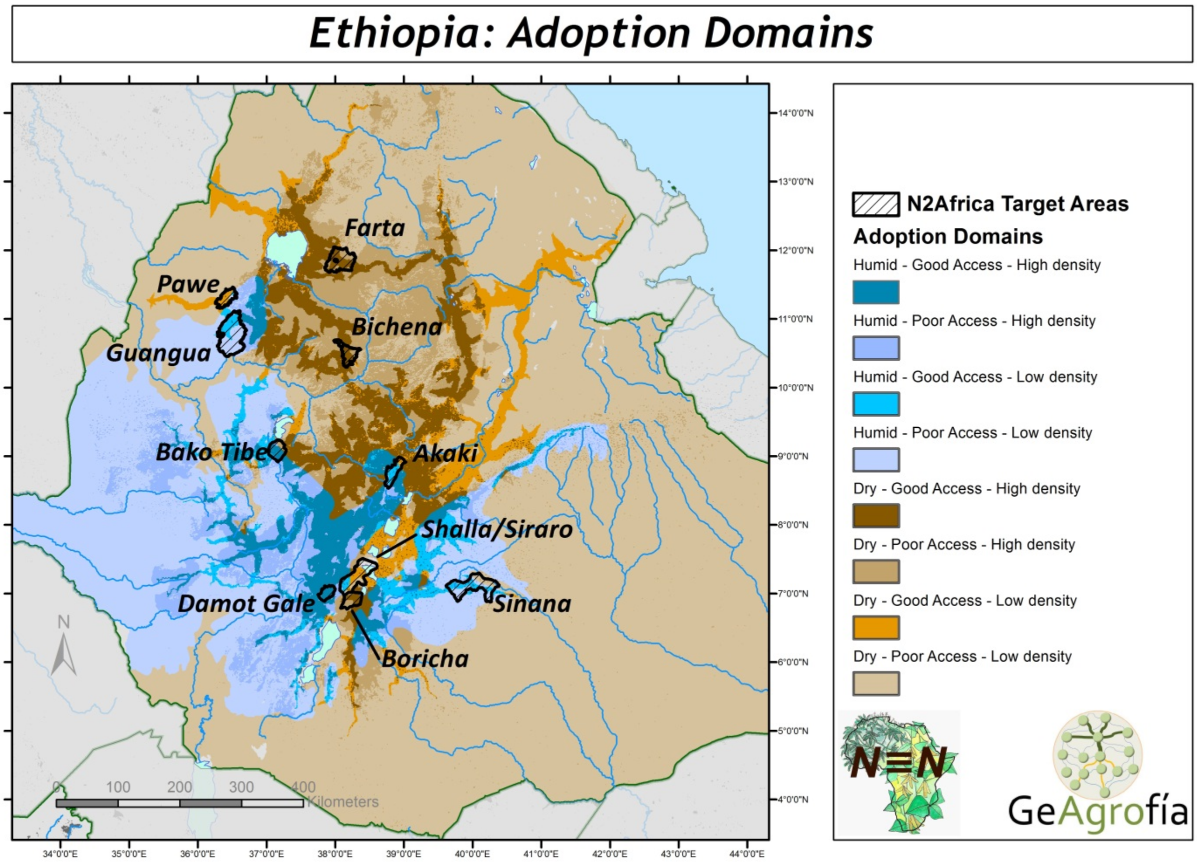


**Figure 22. Faba bean adoption domains**

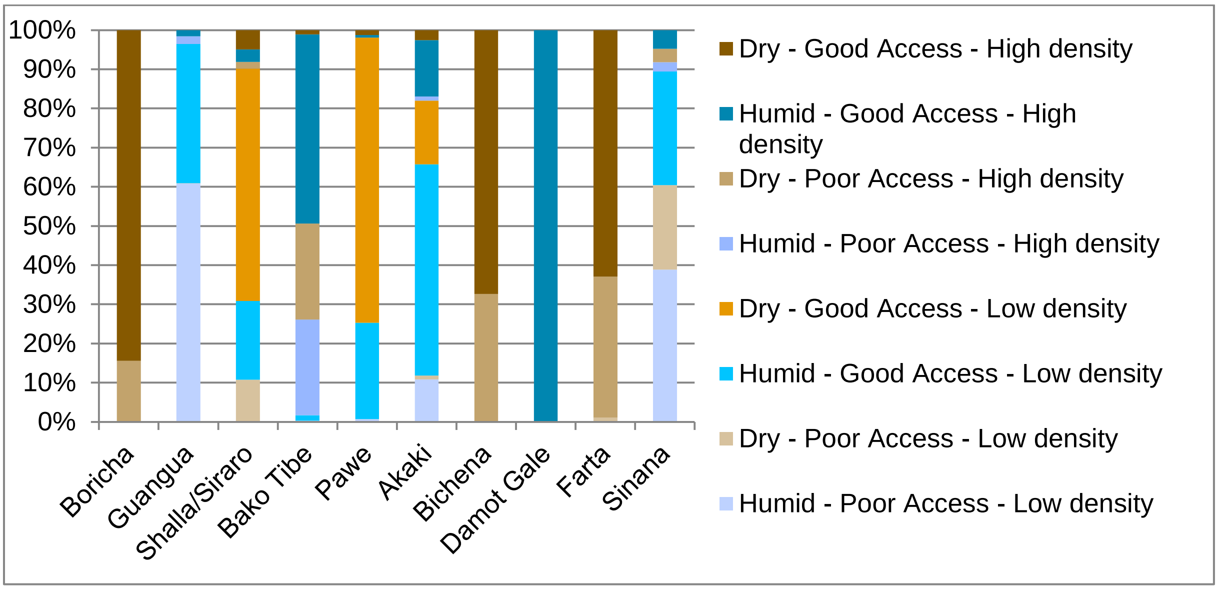


**Figure 23. Characterisation of target districts using adoption domains**

# 6 Conclusions

The adoption domains created for the different N2Africa best bet legume crops in Ethiopia provide a broad structure for implementing research and development activities, and for evaluating the impact of the outcomes of those activities. The hypothesis implicitly proposed here is that adoption of a particular technology package – a legume variety with rhizobium, fertiliser and management practices – would be more likely to be adopted in one domain than another one. This hypothesis can be tested as part of the N2Africa objective on learning and assessing impact (cf. Nkonya et al., 2013). Perhaps more importantly (but with implications for hypothesis testing), the domains should be used to better target the individual components of the technology package.

The choice of a variable to capture the major biophysical differences was not without discussion in Ethiopia. Agro-ecological zones in Ethiopia are characterised by both rainfall distribution and temperature (elevation) and domains that incorporated both these variables were proposed. Temperature was thought to discriminate well between cool highland legumes such as chickpea and especially faba bean, and legumes such as soybeans. However, the domains based on temperature gave the impression that arid areas (like Afar) were similar in terms of agro-ecology to Benishangul-Gumuz. This observation resulted from the presentation of the proposed domains with all the project partners and stakeholders in Ethiopia, and as a consequence of this consultation domains based on moisture were used instead.

The domains presented here are composed of variables that vary considerably across Ethiopia, but present less variability within the individual domains. There are a number of other variables, however, that display large variation over relatively short distances within domains. These include socio-economic variables identified during the review of constraints to adoption (

Table 1), but also comprise terrain, soil fertility and micro-climates. Further stratification is therefore required to control for the variability of these factors within the same domain of a target district.

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# Appendix 1: Accessibility modelling

This annex includes information on the modelling environment within the ArcGIS software, the spatial dataset used, values used, and the python commands.

## Modelling environment: projection

Eth_lam_Az_Eqarea

Projection: Lambert_Azimuthal_Equal_Area

False_Easting: 1000000.000000

False_Northing: 1000000.000000

Central_Meridian: 39.000000

Latitude_Of_Origin: 9.000000

Linear Unit: Meter

GCS_WGS_1984

Datum: D_WGS_1984

## Creation of a Friction surface

Resolution 1km (995m – same as GLC2000)

**Roads**

*gRoads v1*

There is not enough information in the gRoads database for Ethiopia to provide a road speed for every length of road, nor to correlate the Class the road with the speed or seasonality. The road class is based on surface type although there are lots of missing values for even some main roads (e.g. between Adama and Assela).

*Ethiopian Road Authority*

https://cod.humanitarianresponse.info/dataset/ethiopia-roads

An almost identical source to gRoads, but with fewer minor roads, is available with more information on the road surface and seasonality.

Following Nelson (2008) we assume that all road travel is by motorised transport, major roads have a speed of 60kmhrand other roads have a value of 10kmhr, while off road travel is foot based and walking speed depends on landcover.

In contrast to Nelson we also consider that road transport – particularly heavily-laden trucks – will be affected by slope in a similar manner.

| Type | Time |
|---|---|
| All weather paved | 1 mins per km |
| All weather gravel | 1 mins per km |
| Dry weather road | 6 mins per km |
| Motorable tracks | 8 mins per km |

Three raster grids are made – first the all-weather roads, next the dry weather roads and finally the other tracks. This ensures that when the grids are merged the all-weather roads take precedence.

When the road lines are converted to raster, especially with a 1km resolution, it is common that more than one road type will be encountered in any particular cell. To ensure that the raster is given the value for the fastest road the different road types need to be selected from the line feature dataset, converted to a layer and each class converted to raster. Each raster needs to be reclassified with the time value ( in seconds) and combined using a Con statement.

```
arcpy.gp.Reclassify_sa("eth_road_lam1","VALUE","1 60;1 2 60;NODATA 0","SPATAL DATA PATH/Africa/africa/N2Africa/eth_road_60","DATA")
arcpy.gp.Reclassify_sa("eth_road_lam2","VALUE","1 360;NODATA 0","SPATAL DATA PATH/Africa/africa/N2Africa/eth_road_360","DATA")
arcpy.gp.Reclassify_sa("eth_road_lam3","VALUE","1 480;NODATA 0","SPATAL DATA PATH/Africa/africa/N2Africa/eth_road_480","DATA")
arcpy.gp.Con_sa("eth_road_60","eth_road_60","SPATAL DATA PATH/Africa/africa/N2Africa/eth_road_m1","eth_road_360",""""VALUE" = 60""")
arcpy.gp.Con_sa("eth_road_m1","eth_road_480","SPATAL DATA PATH/Africa/africa/N2Africa/eth_road_m2","eth_road_m1",""""VALUE" = 0""")
```

**Land use**

*ILRI*

The source of this dataset is unknown.

http://192.156.137.110/gis/search.asp?id=459

*GLC2000v5 (African regional dataset)*

We follow Nelson (2008):

| Name | Time |
|---|---|
| Background | 60 mins per km |
| Closed evergreen lowland forest | 60 mins per km |
| Degraded evergreen lowland forest | 48 mins per km |
| Submontane forest (900 -1500 m) | 60 mins per km |

| | |
|---|---|
| Montane forest (>1500 m) | 60 mins per km |
| Swamp forest | 60 mins per km |
| Mangrove | 60 mins per km |
| Mosaic Forest / Croplands | 36 mins per km |
| Mosaic Forest / Savanna | 48 mins per km |
| Closed deciduous forest | 60 mins per km |
| Deciduous woodland | 36 mins per km |
| Deciduous shrubland with sparse trees | 36 mins per km |
| Open deciduous shrubland | 36 mins per km |
| Closed grassland | 36 mins per km |
| Open grassland with sparse shrubs | 36 mins per km |
| Open grassland | 36 mins per km |
| Sparse grassland | 24 mins per km |
| Swamp bushland and grassland | 60 mins per km |
| Croplands (>50%) | 36 mins per km |
| Croplands with open woody vegetation | 36 mins per km |
| Irrigated croplands | 36 mins per km |
| Tree crops | 36 mins per km |
| Sandy desert and dunes | 24 mins per km |
| Stony desert | 24 mins per km |
| Bare rock | 24 mins per km |
| Salt hardpans | 24 mins per km |
| Waterbodies | Replaced by Lakes |
| Cities | Replaced by Urban areas |

arcpy.gp.Reclassify_sa("eth_glc_lam","Africa_v5_legend.CLASSNAMES","Background 3600;'Closed evergreen lowland forest' 3600;'Submontane forest (900 -1500 m)' 3600;'Montane forest (>1500 m)' 3600;Mangrove 3600;'Mosaic Forest / Croplands' 2160;'Mosaic Forest / Savanna' 2880;'Deciduous woodland' 2160;'Deciduous shrubland with sparse trees' 2160;'Open deciduous shrubland' 2160;'Closed grassland' 2160;'Open grassland with sparse shrubs' 2160;'Open grassland' 2160;'Sparse grassland' 1440;'Swamp bushland and grassland' 3600;'Croplands (>50%)' 2160;'Croplands with open woody vegetation' 2160;'Irrigated croplands' 2160;'Sandy desert and dunes' 1440;'Stony desert' 1440;'Bare rock' 1440;Waterbodies 3600;Cities 3600;NODATA 3600","SPATAL DATA PATH/Africa/africa/N2Africa/eth_glc_rcl","DATA")

**Lakes**

arcpy.gp.Reclassify_sa("eth_lake_lam","Value","28.605220794677734 3045.10205078125 5000;NODATA 0","SPATAL DATA PATH/Africa/africa/N2Africa/eth_lake_rcl","DATA")

**Urban areas**

There are some small errors in the urban extents spatial dataset (CIESIN et al., 2011) but despite this the coverage of urban areas is more widespread than the urban areas in the GLC2000 dataset and the ILRI source has no land use class for urban areas at all and classes most of Addis Ababa as a swamp.

| Name | Time |
|---|---|
| Urban extent | 2 mins per km |

arcpy.gp.Reclassify_sa("eth_glur_lam","VALUE","1 3600;2 120;NODATA 3600","SPATAL DATA PATH/Africa/africa/N2Africa/eth_glur_rcl","DATA")

**Base times**

The order of the inputs into the base times is:

Landcover

Lakes

Urban

Roads

arcpy.gp.Con_sa("eth_lake_rcl","eth_lake_rcl","SPATAL DATA PATH/Africa/africa/N2Africa/eth_base_1","eth_glc_rcl",""""VALUE" = 5000""")

arcpy.gp.Con_sa("eth_glur_rcl","eth_glur_rcl","SPATAL DATA PATH/Africa/africa/N2Africa/eth_base_2","eth_base_1",""""VALUE" = 120""")

arcpy.gp.Con_sa("eth_road_m2","eth_base_2","SPATAL DATA PATH/Africa/africa/N2Africa/eth_base_3","eth_road_m2",""""VALUE" = 0""")

**Slope**

Slope was calculated in ArcMap from SRTM elevation grid

“v = v0e-ks

Where:

v = off road foot based velocity over the sloping terrain,

v0 = the base speed of travel over flat terrain, 5km/hr in this case,

s = slope in gradient (metres per metre) and,

k = a factor which defines the effect of slope on travel speed

For this case we assume a base walking speed of 5km/hr and k = 3.0 and constant for uphill and downhill travel. The velocities over the slope grid were computed and then converted into a friction factor by dividing the base speed by the slope speed. This was then used as a multiplier against foot-based travel components."

Nelson (2008) only applied slope to walking, perhaps because there was no comparable source for modifying the velocity of motorised transport, there is some evidence from developed countries on the effect of slope on transport speed which suggest a similar relationship (Gillespie, 1985 Methods for Predicting Truck Speed Loss on Grades) and also in developing countries (FAO, 1989: 13/5. Watershed management field manual - Road design and construction in sensitive watersheds, 1989 (E*) http://www.fao.org/docrep/006/t0099e/T0099e02.htm).

FF =1/(EXP(-3*C4))

C4 =TAN(B4* PI()/180)

B4 = angle in degrees

Slope was calculated in ArcMap from SRTM elevation grid

Srtm_slp_lam

Slope grid was converted to points but the file size was too large.

Slope grid split into 12 smaller raster grids

Srtm_slp_00 to srtm_slp_11

Each grid was converted to points

Eth_slp_pt00 to eth_slp_pt11

Each point file was converted back into a grid albeit with a larger cellsize, and point values were averaged for each grid cell

Srtm_lam_00 to srtm_lam_11

Resulting grids were mosaiced and average values were calculated for any overlaps among the grids

Eth_slp_lam

with the same resolution as the GLC2000. This avoids the resampling problems when only the value of the centre raster is used – for instance in the raster calculator.

Slope was converted from degrees to vertical metres per horizontal metre

arcpy.gp.RasterCalculator_sa("""Tan(("eth_slp_lam" * (math.pi / 180)))""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_slp_m")

Metres-in-metre slope grid was multiplied by -3 and used as the power of the exponential function and the inverse was used as the friction factor.

arcpy.gp.RasterCalculator_sa(""""eth_slp_m" * -3""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_slp_-3m")

arcpy.gp.RasterCalculator_sa("""Exp("eth_slp_-3m")""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_slp_e-3m")

arcpy.gp.RasterCalculator_sa("""1 / "eth_slp_e-3m"""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_slp_ff")

The resulting friction factor grid had values between 1 and 22.

#### Elevation

We consider that inhabitants are well adapted to their elevation zone, and that elevation will not have an effect on speed.

#### Friction grid

arcpy.gp.RasterCalculator_sa(""""eth_base_3" * "eth_slp_ff"""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_friction")

## Costdistance modelling

#### Common bean

*Most important markets*

arcpy.PointToRaster_conversion("eth_comb_lam 5","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_5","MOST_FREQUENT","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_comb_5","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb5all","#","eth_comb_5","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb5acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb5dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_comb5acc" / 995.1510667)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb5int")

*Next important markets*

arcpy.PointToRaster_conversion("eth_comb_lam2 4","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_42","MOST_FREQUENT","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_comb_42","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb42all","#","eth_comb_42","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb42acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb42dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_comb42acc" / 995.1510667)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb42int")

*Less important markets*

arcpy.PointToRaster_conversion("eth_comb_lam 3","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_3","MAXIMUM","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_comb_3","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb3all","#","eth_comb_3","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb3acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb3dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_comb3acc" / 995.1510667)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb3int")

*Least important markets*

arcpy.PointToRaster_conversion("eth_comb_lam 2","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_2","MAXIMUM","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_comb_2","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb2all","#","eth_comb_2","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb2acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb2dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_comb2acc" / 995.151066729768)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb2int")

*Combination of markets*

arcpy.RasterCalculator_sa("Con(/\eth_comb5int/\ > 28800, Con(/\eth_comb4int/\ > 21600, Con(/\eth_comb3int/\ > 14400, Con(/\eth_comb2int/\ > 3600, 0 , 1) , 1) , 1) , 1)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_comb_bin")

replaced by

arcpy.gp.RasterCalculator_sa("""Con("eth_comb5int" > 28800 , Con("eth_comb42int" > 21600, Con("eth_comb3int" > 14400 , Con("eth_comb2int" > 3600, 0, 1) , 1) , 1) , 1)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_bin2")

arcpy.RasterToPolygon_conversion("eth_comb_bin2","SPATAL DATA PATH/Africa/africa/N2Africa/eth_comb_bin2_lam.shp","NO_SIMPLIFY","VALUE")

**Chickpea**

*Most important markets*

arcpy.PointToRaster_conversion("eth_ckpea_lam selection","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea_5","MAXIMUM","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_ckpea_5","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea5all","#","eth_ckpea_5","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea5acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea5dir")

arcpy.RasterCalculator_sa("Int(/\eth_ckpea5acc/\ / 995.151066729768)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea5int")

*Next important markets*

arcpy.PointToRaster_conversion("eth_ckpea_lam 4","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea_4","MOST_FREQUENT","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_ckpea_4","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea4all","#","eth_ckpea_4","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea4acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea4dir")

arcpy.RasterCalculator_sa("Int(/\eth_ckpea4acc/\ / 995.151066729768)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea4int")

*Less important markets*

arcpy.PointToRaster_conversion("eth_ckpea_lam 3","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea_3","MOST_FREQUENT","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_ckpea_3","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea3all","#","eth_ckpea_3","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea3acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea3dir")

*Least important markets*

arcpy.PointToRaster_conversion("eth_ckpea_lam 2","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea_2","MOST_FREQUENT","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_ckpea_2","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea2all","#","eth_ckpea_2","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea2acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea2dir")

arcpy.RasterCalculator_sa("Int(/\eth_ckpea2acc/\ / 995.151066729768)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea2int")

*Combination of markets*

arcpy.RasterCalculator_sa("Con(/\eth_ckpea5int/\ > 28800, Con( /\eth_ckpea4int/\ > 21600 , Con( /\eth_ckpea3int/\ > 14400 , Con( /\eth_ckpea2int/\ > 3600 , 0 , 1) , 1 ) , 1 ) , 1 )","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_ckpea_bin")

**Faba bean**

*Most important markets*

arcpy.PointToRaster_conversion("eth_faba_lam 5","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba_5","MOST_FREQUENT","NONE","995.151066729768") arcpy.gp.CostAllocation_sa("eth_faba_5","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba5all","#","eth_faba_5","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba5acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba5dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_faba5acc" / 995.151066729768 )""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba5int")

*Next important markets*

arcpy.PointToRaster_conversion("eth_faba_lam 4","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba_4","MOST_FREQUENT","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_faba_4","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba4all","#","eth_faba_4","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba4acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba4dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_faba4acc" / 995.151066729768)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba4int")

*Less important markets*

arcpy.PointToRaster_conversion("eth_faba_lam 3","FID","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba_3","MOST_FREQUENT","NONE","995.151066729768")

arcpy.gp.CostAllocation_sa("eth_faba_3","eth_friction","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba3all","#","eth_faba_3","VALUE","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba3acc","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba3dir")

arcpy.gp.RasterCalculator_sa("""Int("eth_faba3acc" / 995.151066729768)""","SPATAL DATA PATH/Africa/africa/N2Africa/eth_faba3int")

*Least important markets*

*Combination of markets*

arcpy.RasterCalculator_sa("Con(/\eth_faba5int/\ > 28800, Con(/\eth_faba4int/\ > 21600, Con( /\eth_faba3int/\ > 14400 , 0 ,1 ) ,1 ) , 1 )","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_faba_bin")

**Soybean**

*Most important markets*

arcpy.PointToRaster_conversion("eth_soyb_lam 5","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb_5","MOST_FREQUENT","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_soyb_5","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb5all","#","eth_soyb_5","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb5acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb5dir")

arcpy.RasterCalculator_sa("Int(/\eth_soyb5acc/\ / 995.151066729768)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb5int")

*Next important markets*

*Less important markets*

*Least important markets*

arcpy.PointToRaster_conversion("eth_soyb_lam 1","FID","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb_1","MOST_FREQUENT","NONE","995.151066729768")

arcpy.CostAllocation_sa("eth_soyb_1","eth_friction","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb1all","#","eth_soyb_1","VALUE","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb1acc","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb1dir")

arcpy.RasterCalculator_sa("Int(/\eth_soyb1acc/\ / 995.151066729768)","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb1int")

*Combination of markets*

arcpy.RasterCalculator_sa("Con(/\eth_soyb5int/\ > 28800, Con(/\eth_soyb1int/\ > 1800,0,1) , 1 )","SPATAL DATA PATH/AFRICA/AFRICA/N2AFRICA/eth_soyb_bin")

# List of project reports

1. N2Africa Steering Committee Terms of Reference
2. Policy on advanced training grants
3. Rhizobia Strain Isolation and Characterisation Protocol
4. Detailed country-by-country access plan for P and other agro-minerals
5. Workshop Report: Training of Master Trainers on Legume and Inoculant Technologies (Kisumu Hotel, Kisumu, Kenya-24-28 May 2010)
6. Plans for interaction with the Tropical Legumes II project (TLII) and for seed increase on a country-by-country basis
7. Implementation Plan for collaboration between N2Africa and the Soil Health and Market Access Programs of the Alliance for a Green Revolution in Africa (AGRA) plan
8. General approaches and country specific dissemination plans
9. Selected soyabeans, common beans, cowpeas and groundnuts varieties with proven high BNF potential and sufficient seed availability in target impact zones of N2Africa Project
10. Project launch and workshop report
11. Advancing technical skills in rhizobiology: training report
12. Characterisation of the impact zones and mandate areas in the N2Africa project
13. Production and use of rhizobial inoculants in Africa
18. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
19. Quality assurance (QA) protocols based on African capacities and international existing standards developed
20. Collection and maintenance of elite rhizobial strains
21. MSc and PhD status report
22. Production of seed for local distribution by farming communities engaged in the project
23. A report documenting the involvement of women in at least 50% of all farmer-related activities
24. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
25. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
26. A revised manual for rhizobium methods and standard protocols available on the project website
27. Update on Inoculant production by cooperating laboratories
28. Legume Seed Acquired for Dissemination in the Project Impact Zones
29. Advanced technical skills in rhizobiology: East and Central African, West African and South African Hub
30. Memoranda of Understanding are formalized with key partners along the legume value chains in the impact zones
31. Existing rhizobiology laboratories upgraded
32. N2Africa Baseline report
33. N2Africa Annual country reports 2011
34. Facilitating large-scale dissemination of Biological Nitrogen Fixation

35. Dissemination tools produced
36. Linking legume farmers to markets
37. The role of AGRA and other partners in the project defined and co-funding/financing options for scale-up of inoculum (banks, AGRA, industry) identified
38. Progress Towards Achieving the Vision of Success of N2Africa
39. Quantifying the impact of the N2Africa project on Biological Nitrogen Fixation
40. Training agro-dealers in accessing, managing and distributing information on inoculant use
41. Opportunities for N2Africa in Ethiopia
42. N2Africa Project Progress Report Month 30
43. Review & Planning meeting Zimbabwe
44. Howard G. Buffett Foundation – N2Africa June 2012 Interim Report
45. Number of Extension Events Organized per Season per Country
46. N2Africa narrative reports Month 30
47. Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda
48. Opportunities for N2Africa in Tanzania
49. Background information on agronomy, farming systems and ongoing projects on grain legumes in Ethiopia
50. Special Events on the Role of Legumes in Household Nutrition and Value-Added Processing
51. Value chain analyses of grain legumes in N2Africa: Kenya, Rwanda, eastern DRC, Ghana, Nigeria, Mozambique, Malawi and Zimbabwe
52. Background information on agronomy, farming systems and ongoing projects on grain legumes in Tanzania
53. Nutritional benefits of legume consumption at household level in rural sub-Saharan Africa: Literature study
54. N2Africa Project Progress Report Month 42
55. Market Analysis of Inoculant Production and Use
56. Identified soyabean, common bean, cowpea and groundnut varieties with high Biological Nitrogen Fixation potential identified in N2Africa impact zones
57. A N2Africa universal logo representing inoculant quality assurance
58. M&E Workstream report
59. Improving legume inoculants and developing strategic alliances for their advancement
60. Rhizobium collection, testing and the identification of candidate elite strains
61. Evaluation of the progress made towards achieving the Vision of Success in N2Africa
62. Policy recommendation related to inoculant regulation and cross border trade
63. Satellite sites and activities in the impact zones of the N2Africa project
64. Linking communities to legume processing initiatives
65. Special events on the role of legumes in household nutrition and value-added processing
66. Media Events in the N2Africa project
67. Launch N2Africa Phase II – Report Uganda

68. Review of conditioning factors and constraints to legume adoption and their management in Phase II of N2Africa
69. Report on the milestones in the Supplementary N2Africa grant
70. N2Africa Phase II Launch in Tanzania
71. N2Africa Phase II 6 months report
72. Involvement of women in at least 50% of all farmer related activities
73. N2Africa Final Report of the First Phase: 2009-2013
74. Managing factors that affect the adoption of grain legumes in Uganda in the N2Africa project
75. Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project

# Partners involved in the N2Africa project

A2N

Bayero University Kano (BUK)

Caritas Rwanda

)

Diobass

Eglise Presbyterienne Rwanda

Kwame Nkrumah University of science and Technology

Resource Projects-Kenya

SARI

Sasakawa Global; 2000

Université Catholique de Bukavu

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